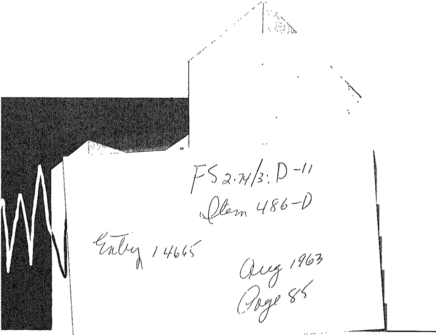
NOISE IN HOSPITALS



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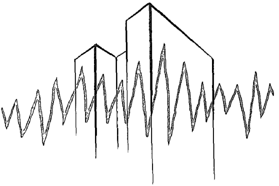
U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

NOISE IN HOSPITALS

AN ACOUSTICAL STUDY OF NOISES AFFECTING THE PATIENT



U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Division of Hospital and Medical Facilities
Architectural and Engineering Branch
Washington 25, D.C.

FOREWORD

Noise has long been recognized as a major source of annoyance to hospital patients and can adversely affect them both physiologically and psychologically. Although many studies on the effects of noise, particularly in industry, have been conducted, little has been done to minimize the problem of noise in hospitals.

The growing diversity of hospital services, the increased use of mechanical and electrical equipment as therapeutic and labor-saving devices, and the use of lighter weight construction materials tend to increase the problems of noise control. The transmission of sounds, through the building structure and through the air, that originate from the numerous types of equipment necessary for the operation and maintenance of a hospital building adds to these problems. The activities of personnel, patients, and visitors are also responsible for a proportionate amount of the noise within the hospital environment.

The findings and recommendations of this study relate to the major noise sources common to most hospitals. Obviously, variations exist among the design of the buildings and the hospital administrations. The purpose of this study is to prescribe practical ways to control or eliminate the causes of noisy situations. The report emphasizes the need for a program not only for checking the mechanical and operational sources of noise but also for thoroughly briefing personnel on work activities contributing to noise. Such a program can provide an effective means for eliminating many of the causes of hospital noises.

These studies, conducted by consulting engineers in acoustics under an Intramural Research Project Grant of the Division of Hospital and Medical Facilities, U.S. Public Health Service, would not have been possible without the cooperation and assistance of the hospital administrators and patients. It should be understood, of course, that the report is not intended to criticize or to evaluate any hospital for a situation pointed out in the findings, but rather to indicate some of the major causes of noises in many hospitals and to recommend steps that can be taken to reduce or eliminate many of these typical noise sources.

It is hoped that the technical points, detailed measurements, and discussion of specifications will serve as helpful guides to hospital administrators, architects, engineers, and equipment manufacturers in appraising—and in correcting—the noise sources in existing hospitals and in controlling potential noises when planning new construction.

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ACKNOWLEDGMENTS

This special study was carried out under the auspices of the Public Health Service by:
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SUMMARY

To determine the types, sources, and extent of noise throughout hospitals, a study was undertaken by a firm of acoustical consultants in collaboration with the Division of Hospital and Medical Facilities (Architectural and Engineering Branch) of the U.S. Public Health Service. This study, which involved eight eastern hospitals, was designed to evaluate the conditions that may contribute to noisy situations, and to determine what changes in the design of buildings and equipment can help to reduce noise in hospitals. The study was also directed toward obtaining predictive acoustical values of mechanical and structural equipment and of personnel practices that contribute to noise. To avoid direct identification of the hospitals surveyed, key letters have been used for each hospital.

The study was conducted in three phases: (1) Physical inspection of each hospital; (2) recorded measurement of noise levels within the hospital in corridor and patient room locations; and (3) questionnaire survey of recently discharged patients.

Whether a sound is interpreted as noise depends upon the acuity of the hearer and his "appraisal" of it. The sounds to which persons become accustomed are those that form part of a continuous background and do not distract their attention. Personal reactions to similar sounds vary widely, from "not noticed" or slight annoyance to extreme discomfort.

The consultants observed during inspection of the medical and nonmedical areas of the hospitals, and simultaneously recorded, annoying sounds and their sources common to most of the hospitals as follows: Talk in corridors and other patient rooms by staff, visitors, and patients; corridor activities such as walking and movement of cleaning equipment, medical carts, and food trays; floor, kitchen, and utility room activities; housekeeping activities; telephones and voice paging systems; and exterior traffic noises such as those from the service driveways, sirens, personnel and visitors' parking, and nearby highways.

Another group of sounds observed and recorded involve functional sources. These sounds are caused by mechanical, operational, and structural equipment, or service facilities. The more predominant sources are: refrigerators in floor kitchens and at nurses' stations, air conditioning and window fans, roof blowers, cycling of drinking fountains, cabinet drawers, compressor piping and pumps, elevators and their accompanying brake- and switch-gear sounds, and stairways that reverberate sounds from footfalls and conversation.

Most causes of these noises were the results of inadequacies pertaining to the same types of equipment and facilities in a number of the hospitals. Some of these included improper location of mechanical and operational equipment and facilities, inadequate use of vibration-isolation methods for equipment, faulty installation or poor design of equipment, communications systems, housekeeping activities, patient service facilities, personnel activities, and visitors.

As part of the survey procedure, questionnaires were sent to former patients of the hospitals. They were told that the questionnaire was not meant to be a "complaint" form but an attempt to help analyze the basis of predominant or disturbing noises which may have been noticed. Comments by the respondents ranged from observations such as that of an airplane flying over the building (this particular hospital was not in the path of an airfield, which would have been adequate cause for this type of comment) to that of overhearing conversation of other patients and staff or the spray of lawn sprinklers. Notwithstanding the element of personal reactions, many of the comments on noise were justified and coincided with the consultants' observations.

Graphic measurements and tape recordings of the overall composition of the hospital noises and sounds, together with the consultants' observations and the patients' comments, serve as a base for evaluating the noises and their sources and for recommending definitive corrective measures.

In the early planning stage of a hospital, careful consideration should be given to the site, especially the possible traffic noises of highways, railroads, or airport in the vicinity. Also, parking areas for visitors and personnel should be located so that they will not contribute to outdoor noise. Nursing and convalescent areas should be shielded from traffic sounds.

Interior sounds, of course, exceed the number of exterior sounds. The integral mechanical units of the hospital structure are often inherently noisy. These sources transmit noises by vibration through the structure, the piping, the ducts, and the air. Premeasurements can be made of equipment to determine the noise potential of its design and installation. In addition, initial preventive measures can be employed which will be helpful in minimizing the noise-producing potential of equipment.

The noises caused by hospital personnel as they attend to patients' needs or to other activities, as well as the noises caused by the patients and their visitors (among the most difficult to abate), can best be controlled through administrative directives.

Tables of recommended maximum sound levels for various types of equipment, as well as sound level noise criteria for various spaces within the hospital, are given and will be useful in specifying minimum noise levels in selecting equipment. A summary of recommendations is presented in checklist form (see page 73) to facilitate reference to acoustical details and methods for control of noise in hospitals. The recorded graphic measurements of the sounds and noises in the hospitals studied are shown in appendix B.

Part I

APPRAISING NOISE IN HOSPITALS

Chapter 1

INTRODUCTION

This study is based on a survey of the noises found in modern hospitals and of the patients' responses to the noises; it includes analyses of the sources of such noises and recommendations for noise reduction.

Noisy conditions that may affect hospital patients and staff were explored during the survey and an attempt was made to determine the basis for complaints about noise. Since comfort of an ill person is often related to a quiet environment, it was felt that noisy conditions might have an adverse effect on patients' comfort and morale.

Awareness of these problems led to the initiation of this survey and study. It was hoped that such a study might supplement the meager information now available on possible remedies for this problem, which is of growing concern to hospitals and hospital associations throughout the Nation.

The survey and study was conducted by Lewis S. Goodfriend* and R. L. Cardinell* serving as Special Consultants to the Division of Hospital and Medical Facilities, Public Health Service, U.S. Department of Health, Education, and Welfare, during the spring and summer of 1958.

OBJECTIVES

The survey was undertaken to provide a realistic appraisal of hospital noise and to determine how such noise might be reduced through design and equipment changes. Charts 1–135, appendix B, showing the results of measurements made in hospitals, may be useful to hospital administrators, architects, and engineers in planning and designing quieter hospitals.

Although budgetary considerations may limit expenditures for noise control, those responsible for planning a hospital should realize that added days of hospital care, extended convalescence, or incomplete recovery may result from patients' insufficient bed rest. Moreover, the monetary loss to the community and to the individual in terms of lost working days from overlong hospitalization is a further reason for providing quieter hospital conditions.

ADEQUATE DESIGN GUIDES LACKING

A search of the literature shows a dearth of guide material for floor plans providing for quiet areas for patient rooms in relation to facilities, although attention has been given to traffic analyses and personnel needs. There is also little information available on the selection of mechanical equipment and specifications for minimum noise levels in hospitals.

When this study was undertaken, no systematic analysis of the need for sound absorption or sound isolation in hospitals had been made. Lacking such an analysis, hospital design guides have been recommending merely that acoustical absorbing materials be used in certain hospital areas, such as corridors in patient units, nurses' stations, labor rooms, utility rooms, floor pantries, kitchens, "one bedroom in each nursing unit for use as a quiet room," nursery, basal metabolism rooms, electrocardiography rooms, and outpatient waiting rooms.*† No one has felt that it may be imperative to place acoustical materials in patient rooms.

The most extensive efforts apparently have been directed toward obtaining maximum capabilities of nursing personnel and the most efficient mechanical equipment to facilitate hospital operation. Considerable attention has also been given, on the part of civic authorities, toward obtaining quiet in the exterior areas of hospitals by posting admonitory signs in the immediate vicinity.

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*Lewis S. Goodfriend & Associates, Little Falls, N.J.

*U.S. Department of Health, Education, and Welfare, Public Health Service. *Design and Construction of General Hospitals.* F. W. Dodge Corp., New York, in collaboration with Modern Hospital Publishing Co., Chicago, Ill. 1953. 214 pp.

†U.S. Department of Health, Education, and Welfare, Public Health Service. *Public Health Service Regulations, Part 53—Pertaining to the Hospital and Medical Facilities Survey and Construction Legislation.* PHS Publication No. 930–A–1. Division of Hospital and Medical Facilities, Washington 25, D.C. 1962.

The heavy construction materials used in the past provided many hospitals with a relatively quiet environment. However, with the advent of lighter construction materials as well as changes in hospital design, noise problems have arisen in many new hospitals.

BACKGROUND OF HOSPITALS SURVEYED

The findings in this report are based on a study of eight hospitals. Of these, seven were constructed since 1949 and have less than 150 beds. One of this group was an economically designed, privately financed hospital that was included to compare its design and materials with those of the other hospitals. The eighth was an 800-bed hospital that was included to determine if any special noise factors were related to size. At the other end of the scale was a 24-bed hospital. Figures 1 through 13 show floor plans and plots of the areas surveyed in the study.

For geographic convenience, the hospitals chosen are located within a reasonable traveling distance from the consultants' office. These hospitals are considered "typical" in construction and service for their size. It was therefore felt that it was not necessary to include other hospitals in the survey.

METHODS OF SURVEY

The study program was divided into three parts: (1) physical inspection of each hospital; (2) measurement of noise levels within the hospital in corridor and patient room locations; and (3) a questionnaire survey of recently discharged patients for comments on hospital noises and for their opinions of the effects of the noises on them.

Physical Inspection of Hospital

The physical plant inspection and the noise measurement survey were conducted simultaneously. The extent and types of noises were recorded by using a calibrated microphone and tape recorder. Inasmuch as most hospital noises are repetitive, the recorder was operated only a portion of each hour to register all significant outstanding and background noises. In addition to the tape recording, a continuous loudness index chart was made. Analyses of these data are presented in chapter 4.

Measurement of Noise Levels

A general finding noted during the survey and indicated by the data shows that hospital patient room areas are noiser than most residential sleeping areas in cities or suburbs. The noise levels in a typical patient room (recorded from an unoccupied room with no internal room noise) are above those recommended for sleeping areas in residences.* Various obsolete methods in planning, equipping, and operating the hospitals have contributed to the excessive noise levels.

Installation of acoustical tile in patient rooms and utility rooms greatly diminishes the transmission of noise from the utility rooms to the patient rooms. The use of acoustical tile, as well as specific design and care in selecting equipment, is becoming standard practice in many new hospitals.

Patients' Questionnaire

A questionnaire survey of patients was developed by the consultants and tested during the noise survey at the first two hospitals. After some modifications, the questionnaire and a covering letter from the Public Health Service were mailed to patients recently discharged from all eight hospitals. About 50 percent of the patients replied. The details of the questionnaire survey and the results of the analysis of the data are presented in chapter 3.

The tape recordings of the sounds, investigations, observations, and questionnaires indicate that a number of noises common to hospitals tend to disturb the patients' rest. However, the mailed questionnaire results are not as revealing as the verbal opinions of a few hospitalized patients interviewed by the consultants. Some discharged patients apparently were reluctant to "criticize" while in the hospital, and thus may have softened their evaluation of some noise sources, particularly personnel activity noise which some patients indicated as "inevitable in the operation of any hospital." Nonetheless, there is a reasonable consistency in the results of the studies.

INFLUENCE OF PERSONNEL PERFORMANCE

Hospital personnel can influence the amount of noise generated during their routine work and in their service to patients. Acoustical material, of course, cannot prevent the noise of a bedpan being dropped or the noise caused by a medication cart with a loose, rattling frame. These problems are covered in chapter 5 under Patient Service Facilities. Several of the disturbing sounds were found to originate in personnel activities and could be reduced by modifying procedural routines.

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*Beranek, Leo L., "Revised Criteria for Noise in Buildings," *Noise Control*, Vol. 3, No. 1, January 1957, pp. 19–27.

Legend: Symbols and abbreviations used in the following plans

B	Location of microphone in patient room during sound recording
C	Location of microphone in corridor during sound recording
Adm.	Administration
Bass.	Bassinets
B.P.	Bedpan room
Doc.	Doctors' room
Emer.	Emergency
I.M.	Ice machine
Iso.	Isolation room
Kit.	Kitchen
L.	Linen closet
N.S.	Nurses' station
Pant.	Pantry
P.R.	Patient room (numeral following indicates number of beds)
Rec.	Recovery room
Ster.	Sterilizing room
Sto.	Storage
Sup.	Supply room
Treat.	Treatment room
Util.	Utility room
Wait.	Waiting room

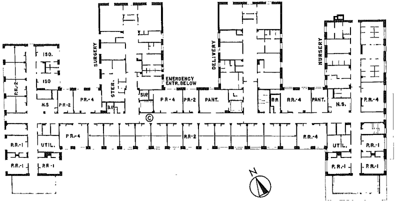


Figure 1. Hospital V—second floor plan.

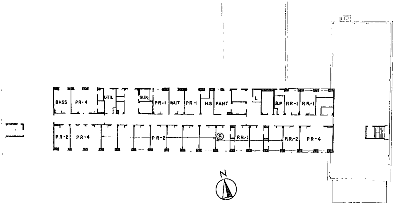


Figure 2. Hospital V—third floor plan.

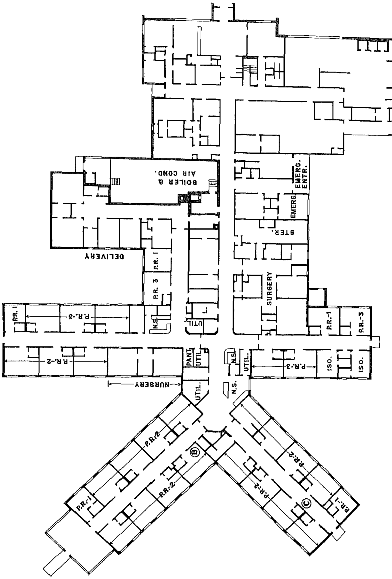


Figure 3. Hospital B—main floor plan.

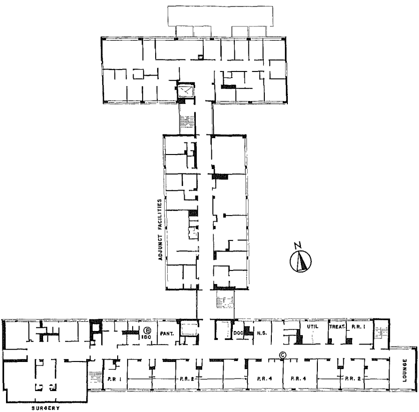


Figure 4. Hospital H—third floor plan.

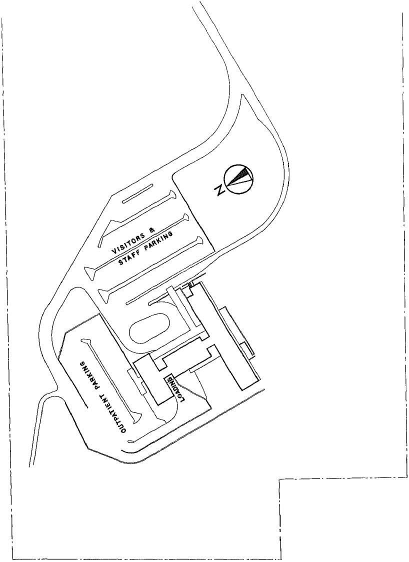


Figure 5. Hospital H—plot plan.

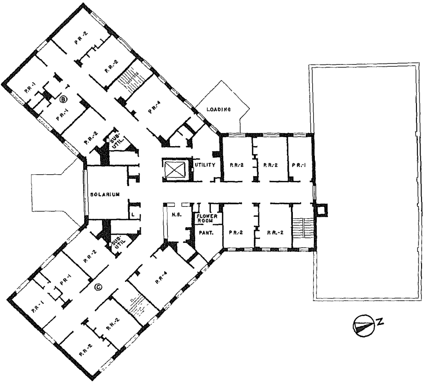


Figure 6. Hospital N—second floor plan.

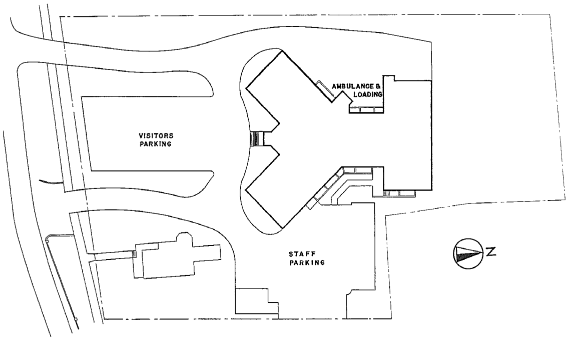


Figure 7. Hospital N—plot plan.

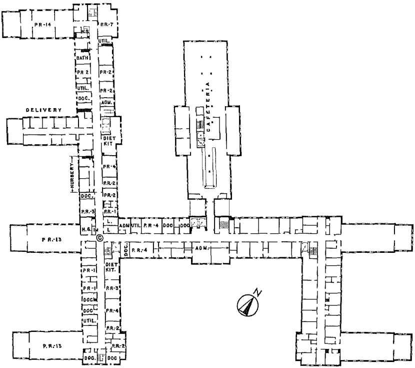


Figure 8. Hospital S—second floor plan.

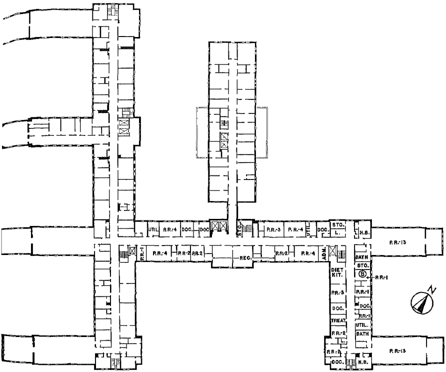


Figure 9. Hospital S—fourth floor plan.

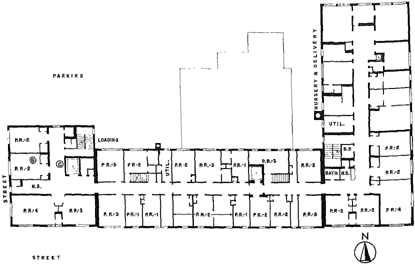


Figure 10. Hospital P—second floor plan.

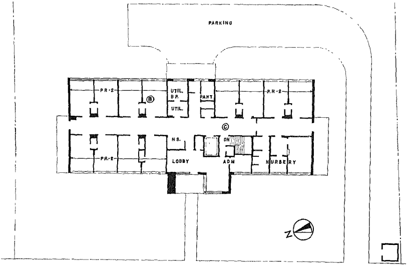


Figure 11. Hospital R—first floor plan.

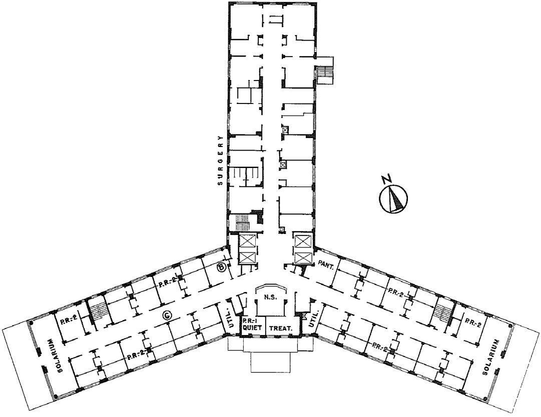


Figure 12. Hospital M—second floor plan.

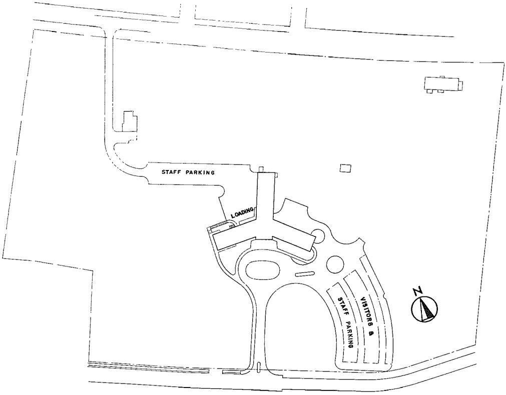


Figure 13. Hospital M—plot plan.

Chapter 2

THE NATURE OF SOUND

WHAT IS IT?

Sound is a pressure wave in air. It originates as a result of an oscillatory motion imparted to air molecules, causing a vibratory chain reaction. This sound wave then spreads in a spherical fashion. If a hard surface is struck, the sound wave is reflected. If a thick, soft surface is struck, the sound wave is partially absorbed. If a small object is hit, the object is immediately surrounded by the sound wave. If a bulky object is hit, the wave bends around the object, leaving an area of shadow and eventually filling in the space behind. If the sound wave impinges on a small opening, such as a crack in a wall, a new wave originates on the opposite side. If the wave strikes the eardrum, the resulting vibration is perceived by the brain as hearing.

A sound is considered loud or soft depending on whether its pressure intensity is great or small. The sound can be low-pitched or high-pitched, depending on the frequency of the vibrating wave (cycles per second, or cps). The pitch increases as the frequency increases. For every doubling of frequency the pitch is increased one octave. For instance, middle C on the piano has a fundamental frequency of 256 cps, while C an octave higher has a fundamental of 512 cps. In general, human hearing encompasses the approximate range from 15 cps to 20,000 cps.

The character and quality, or timbre, of the sound depends on the complexity of its wave. An absolutely pure tone, which is rarely, if ever, encountered, contains only a single frequency. Musical tones contain a dominant fundamental frequency plus a number of harmonics or overtones that are exact multiples of the fundamental and usually of lesser intensity. Sound that is generally considered "noise" most often contains a number of unrelated frequencies. Because of its complexity, a detailed and complete analysis of the sound is usually impractical. The general practice is to divide the sound into bands by means of electrical filters and to measure the sound wave intensity of each band. The bands most commonly used are one octave, one-half octive, or one-third octave in width.

Loudness, a subjective phenomenon, cannot be measured directly with instruments. Instead, it is determined by the intensities of all the frequencies that make up the sound. The overall sound pressure, expressed as a single figure of decibels (db), does not indicate what the brain perceives in the way of loudness.

Noise is often defined as "unwanted sound." This immediately introduces the question of human reactions and psychology. What may be music to one person may be a horrible din to another. In general, a noise is a sound that disturbs, whether the hearer is or is not conscious of annoyance. His reaction is modified by many factors—beyond the scope of this report—and may vary from one time to another.

HOW DOES IT TRAVEL? (PATHS OF SOUND)

Sound is transmitted through a building in two ways:

1. By direct radiation of the sound waves in air; this is known as airborne sound.
2. By transmission through the structure or piping; this is known as structure-borne sound. In most cases, structure-borne sound is transformed into airborne sound before it reaches the hearer's ear.

In open air, the intensity of a sound diminishes rapidly as the distance from the source is increased. This diminution occurs because the original sound power must be distributed over the surface of an ever-increasing sphere. When a sound is confined in a space, such as a room or hallway, the sound power is mostly contained within the boundaries, and the diminishing of intensity does not occur as rapidly as in open air.

Reflected sound waves help to maintain the sound level over great distances, as in a speaking-tube. For instance, although treating a corridor ceiling with acoustically absorbent material eliminates some of the reflected waves, the hard walls and floor continue to carry the sound waves.

Airborne Sound

Airborne sound can travel out an open window, strike a wall or some other part of the structure, and be reflected back to enter a number of adjacent rooms. Moreover, it can readily pass through small openings and cracks. Closing the door to a room effectively reduces the sound entering the room, but if the door is not properly gasketed and sealed at the threshold, much sound will still enter.

Ventilation louvers in doors, regardless of whether they are opaque to light, also offer little resistence to sound.

Thin panels or walls are not very effective in reducing sound transmission. Sound waves are set into motion by the impinging waves and produce new sound waves on the other side. A wall of high mass or of double construction is required to effectively block the transmission of sound between adjacent rooms. Back-to-back electrical outlet boxes often allow sounds to be carried from one room to another.

Structure-borne Sound

Sound waves pass easily through solids and consequently can travel long distances. Structure-borne sound also exhibits the peculiarity of skipping certain areas and reappearing at various distances from the original source.

Structure-borne sound often arises when machinery is not properly isolated from the surrounding structure or connecting pipes. This medium is also responsible for transmitting impact sounds, such as hammering or footsteps.

As was pointed out earlier, structure-borne sound is generally transformed into airborne sound before it becomes audible. At the receiving end, therefore, a panel, wall, or floor is set into vibration because it is in contact with the pipe or part of the structure carrying the solid-borne sound waves. This receiving medium, presenting a large surface to the air, produces airborne waves of considerable dimension. The sounds are amplified in much the same way as the sounding board of a piano magnifies the tones of the strings.

If the panel or wall has a resonant frequency that corresponds to the original sounding source, the resultant airborne sound will be reinforced and especially pronounced. In some instances, panels can be affected by vibrations that do not correspond to their resonant frequencies, and thus produce entirely new sounds as the result of the combined frequencies.

Structure-borne noise can be eliminated by properly isolating machinery and piping from the building, by installing resilient supports, such as pipe hangers, and, where necessary, by providing discontinuities in the structure itself. These are discussed in more detail in chapter 5.

It is far easier to eliminate structure-borne noise in the planning stage than to provide remedial measures after the building is finished. In considering sound isolation in the acoustical design of structures, care should be exercised to eliminate flanking transmission paths. For instance, an improperly fitted door in a double-wall isolating construction for a room can serve as a flanking path and thereby can render useless an otherwise good acoustical construction.

Chapter 3

SUBJECTIVE FINDINGS

An individual's reaction to sound is purely subjective. No existing instrumental technique can positively measure and evaluate such a reaction. Instead, the individual himself must be questioned.

The investigators, while recording the sound measurements, observed and noted various noise sources in the hospitals, which they felt could possibly bother the patients. Later when the patients' questionnaires were analyzed, it was found that certain sounds noted by the investigators were unnoticed by patients. On the other hand, patients were disturbed by sounds which were unnoticed by the investigators.

Some patients tended to take certain sounds for granted, and these sounds were unnoticed. Some reported that certain noises did not bother them, but felt that the sounds might "bother others who were more sick." Several others said they were too ill to be bothered by noise.

INVESTIGATORS' OBSERVATIONS

The consultants observed 14 disturbing sounds prevalent in most of the hospitals surveyed. The noise sources or sounds which annoyed or interfered with sleep of some patients in a majority of the hospitals included: Telephones, radio and television sets, hard heels of visitors and nonnursing personnel, floor-polishing machines, shift changes at night, toilet flushing, and night nurses' coffee break. (These sounds were also corroborated by the patients' questionnaire returns.)

Other disturbing noises originated from: hand trucks for oxygen tanks, bedpan washers, chart cases and racks, scraping of chairs, dragging of furniture, slamming of doors, and oxygen tent equipment.

Additional specific noise sources observed in the individual hospitals are shown in the following lists. The asterisks indicate those sounds which were also found to be sources of annoyance by patients, according to the questionnaire returns. The hospitals surveyed will be referred to by key letters throughout this report.

Specific Interior Noises and Sources

Hospital V

*Dishwasher—pantry is unventilated and door is left open.
Blowers in autoclave room—mounted on shelf without vibration isolation; door to room is louvered and sound escapes to corridor.
*Refrigerator in kitchen—front cover off.
*Dropped pan—nurses say it occurs at least once every night.
*Bedpan washer—room is very small and door is wedged open.
Air conditioner in central supply—mounted on floor without vibration isolation.
*Poorly fitted door to pantry.
*Carts and/or their contents.

Hospital B

Roof blowers.
Bathroom exhaust fans.
Carts—hospital personnel frequently use wheeled stretchers since they make less noise than utility carts.
Flower cart.
Window fan at nurses' station.
Drinking fountain.
Cricket outdoors.

Hospital H

*Drawers at nurses' station.
*Ventilator grille and steam cleaner in bedpan room.
Large metal drum on dolly for trash disposal.
*Medical carts—bottles clinking (rather than wheel noise).
*Pump in boiler room.

*Compressor in roof penthouse—piping not isolated.
*Elevator brake noise.
*Portable scale on wheels.
Cleaning equipment.

Hospital N

Stair door closer squeaks—poorly mounted.
*Food cart in hall—pantry door too small to permit entrance of cart.
Elevator fan.
Transformer and hot water units in basement.
Drinking fountain.
*Toilets and bedpan rooms have louvered doors.
Utility room doors remain open.

Hospital S

*Ice machine—noisy operation and noisy unloading.
Nameplate press in ward office.

Hospital P

Elevator switchgear.
Reverberant stairwell.
*Toilet door poorly hung—strikes against lower jamb.
*Service driveway is close to certain rooms.

Hospital R

Pans.
Food cart.
*Cleaning equipment.
Reverberant stairwell.
*Cabinet doors in pantry.
*Utility room.

Hospital M

*Floor refrigerator.
*Ice machine.
*Air cooler in utility room.
*Drinking fountain.
*Carts—wheels and contents.

The foregoing listings show that there was general agreement between the observations of the investigators and those of the patients. In Hospital B, the average background noise level was relatively low. Those sounds which the investigators noted apparently were not loud enough to be disturbing to the patients. In Hospital S, the average background level was high, and only two noise sources were noted by the investigators. On the other hand, the patients noted 30 annoying sounds (see table 2, Hospital S).

PATIENTS' OPINIONS

The Questionnaire

Questionnaires were mailed to recently discharged patients to determine their reactions. The consultants handled the returns and subsequent tabulations. (The questionnaire form and covering letter are included in appendix A.)

The questionnaire, developed after pretesting two hospitals for obvious existing or potential noise sources, consisted of five parts. The first portion presented a listing of 26 sounds determined from the above observations. Respondents were requested to indicate whether these sounds were not heard, whether they were noticed, or whether they were bothersome.

Topics covered in the remainder of the questionnaire included: Other bothersome sounds not listed in the preceding section; the most bothersome noises, listed according to degree of annoyance; the extent of sound transmission between rooms; specific sounds which awakened the respondent; and additional comments concerning hospital noise.

Some Advantages and Drawbacks of Questionnaire Technique

A major aim of the questionnaire was to determine which noises bothered the patients, regardless of specific sound levels or range. The individual's response to a given sound is affected by many things, such as previous associations, frequency of repetition, prior conditioning, state of mind or mood, and present activity. Therefore, an attempt to determine individual reaction was considered a necessary adjunct to the study.

The most reliable method of obtaining this information would have been through personal interviews. However, because of the excessive cost and time involved, use of the questionnaire was considered more practical. The questionnaire form was made short and simple to encourage replies and to produce the needed information.

As the returns came in, the disadvantages of using the questionnaire method became apparent in the following ways:

1. In general, the number of forms returned was relatively small. This adversely affects adequate statistical analysis.
2. Many queries were incompletely answered, especially by those who regarded this questionnaire as a "complaint form." In many instances, patients who had few or no complaints gave incomplete answers or only had the comment "no complaints." It may, therefore, be surmised that had the patients realized the purpose of the questionnaire, many sounds indicated as "noticed" might otherwise have been marked "bothered."

3. Many patients overlooked, or made allowances for, sounds which they considered necessary or unavoidable.
4. Some responses contained contradictions.
5. There were some misunderstanding about certain types of sounds listed in the questionnaire. One example of this was "call-bell system," which was placed on the form in the event that some hospitals used this system instead of the voice paging system. Despite the fact that none of the hospitals surveyed used the "call-bell system," all respondents stated that this system was noticed. Probably the respondents meant handbells, such as those used in oxygen tents, or other signalling bells, such as a doorbell for night emergency admission.
6. There was also some misidentification of the sounds that were heard. It apparently is difficult for the uninitinted to distinguish between noises such as those of a toilet and bedpan washer, pantry and utility room, or cleaning pail and trash disposal container. Checks against "staff talk in corridors" may have applied to the changes of shift at the nurses' station.

Most of these misinterpretations would have been eliminated through direct interviews, but the cost made this impractical. As it was, the questionnaires proved to be highly informative. All returns were reviewed, and some were edited to clarify any obvious contradictions or misunderstandings. It should be noted, however, that there may still exist some areas of confusion or overlapping in the interpretation of some individual sounds or sound categories listed in the tabulations of the questionnaire replies (table 2).

In general, the comments indicate a fairly high degree of satisfaction with the hospitals. As in almost all instances of subjective reactions, there are differences of opinion. One individual condemns a hospital for being noisy, while another says it is the quietest he has ever been in, and a third says he heard no noise at all. Several respondents commented that they desire a certain amount of noise because it indicates activity. In addition to remarks on sound, many respondents commented on other aspects of operation or management.

Annoyance Scores of Specific Sounds

The tabulations of questionnaire returns resulted in a calculated "annoyance score" for each sound. This was arrived at in the following manner:

In Part C of the questionnaire, respondents were asked to list the most bothersome sounds in decreasing order. A "first place" was assigned a value of 3 points; a "second place," 2 points; and a "third place," 1 point. A value of 1 point was given for each time the sound was indicated as bothersome in Part A of the questionnaire. The total of the assigned values gives the annoyance score for a specific sound.

Because of the small returns and the number of incomplete returns received, it is not advisable to consider the annoyance scores as representing direct ratios of annoyance or irritation. Also, comparisons should not be made between hospitals on the basis of the scores. A large spread between scores in a single hospital, however, may be used to indicate appreciable differences in annoyance, as well as the rank order, of sounds in that hospital.

Tabulations of Annoyance Scores

Table 1 shows the number of usable returns received from each hospital.

Table 1.—Number of questionnaire returns tabulated

Hospital	*Returns*
V	115
B	44
H	51
N	67
S	125
P	46
R	9
M	57
	514

Table 2 shows the noises bothering patients in all the hospitals and the annoyance scores. The first 25 are listed in the order in which they appeared on the questionnaire form. The others are noises added by patients in Part B of the questionnaire. These figures have been tabulated from the individual returns. In a few instances, sounds of a similar nature, listed separately by respondents, have been combined.

Table 2.—Annoyance scores of specific sounds bothering patients

Sounds and sources	Hospital							
	V	B	H	N	S	P	R	M
1. Visitors' talk in corridors	8		5	6	14	2	3	5
2. Staff talk in corridors	32	9	8	9	12	12	1	6
3. Talk in other patients' rooms	25	7	8	8	15	4		12
4. Walking in corridors	5		2	2	7	2		10
5. Slamming doors	7			2		4		
6. Pantry, kitchen, utility room	33		7		7	1	3	
7. Food service: dish and tray clatter	15	1	4	5	9			3
8. Carts: medicine, linen, other	5		2		12	8	1	1
9. Elevators, elevator doors	4		7		19			
10. Voice paging system	1		12	1	11			36
11. Call-bell system: handbells, others	1			1	2			
12. Call buzzers				4		4	4	5
13. Telephones	3	1	1	4	2	11	5	1
14. Radios or television sets	33	14		29	19	2		28
15. Toilet flushing	6		1	4	8	1		
16. Bedpan washer	35		2		3	6		
17. Fans, air conditioners				4	2	3		4
18. Water running from faucet	2			1	8	1		
19. Coolers, fountains, refrigerators								4
20. Cleaning equipment: buckets, trash containers	10	2		1	5	7	2	5
21. Floor polishers	7		6	4		1		5
22. Highway or street traffic	15			10	8	3		4
23. Airplanes			1		1			
24. Trucks at service entrance	8			1	7			5
25. Other service entrance noise	1		1		3			9
26. Other patients in distress	12		9	12		1		15
27. Babies or children crying			6	9		8	8	1
28. Recovery room	34							
29. Nurses' station noise; chart cases	12		4					
30. Pans or objects dropped or banged	4				4	5		
31. Chair dragged or scraped; furniture moved	2				3			1
32. Noisy patients: talk, snore, etc	4			2	5			
33. Roommate: ill, visitors, therapy equipment			2			13		4
34. Employees: staff cars arrive at night					3			2
35. Sirens of emergency vehicles	2			3				
36. Cleaning staff talk in corridors	1							6
37. Doctors discuss patients' symptoms in corridors			1	4				
38. Noise on stairway	4							
39. Ice pitcher service and pickup, midnight		4						
40. Ice water service, 5:30 a.m.					53			
41. Delivery room sounds (door left open)						4		
42. Radiator hammer						4		
43. Ambulance or police radios left on						4		
44. Oxygen tent equipment								2
45. Window shade (flaps during storms)	1							

Table 2.—Annoyance scores of specific sounds bothering patients—Continued

Sounds and sources	Hospital							
	V	B	H	N	S	P	R	M
46. Bedrolls	1							
47. Noise at night: not specified			5					
48. Machinery at night: not identified			3					
49. Noise from laundry					3			
50. Ice cube machine					2			
51. Construction work						1		
52. Bed curtains						1		
53. Emergency admission at night								3
54. Rustle of night nurse's skirts								3
55. Visitors after hours in hall and ward				8				
56. Patients describe operations		4						
57. Staff talk in ward					1			
58. Traffic at entrance								1
59. Loud talk/children at entrance					5			
60. Auto racetrack near site			5					
61. Lawn sprayers	4							
Total number of specific annoying sounds for each hospital	33	8	23	24	30	26	8	27

It is significant that some sounds, although not necessarily having the highest annoyance scores, were prevalent in most of the hospitals. These are shown in table 3.

Table 3.—Annoying sounds common to most hospitals surveyed

Sounds and sources	*Number of hospitals*
Telephones	8
Staff talk in corridors	8
Visitors' talk in corridors	7
Talk in other patients' rooms	7
Cleaning equipment: buckets, trash containers	7
Walking in corridors	6
Food service: dish and tray clatter	6
Carts: medicine, linen, other	6
Radios or television sets	6
Pantry, kitchen, utility room	5
Voice paging	5
Toilet flushing	5
Floor polishers	5
Traffic	5
Other patients in distress	*5
Babies or children crying	*5

*If considered together, would total 6 hospitals.

Table 4 is derived by combining the rank-order positions according to the annoyance scores and prevalence in the hospitals surveyed.

Table 4.—Most prevalent sounds arranged in order of annoyance

Rank position	*Sound*
1	Radios or television sets
2	Staff talk in corridors
3	Other patients in distress and recovery room sounds
4	Voice paging
5	Talk in other rooms
6	Babies or children crying
7	Telephones
8	Pantry, kitchen, utility room

The sounds transmitted between rooms and the sounds which awakened patients were indicated in Parts D and E of the questionnaire. The responses are shown in table 5.

Table 5.—Sound transmission and sleep interference

Hospital	Noise heard from adjacent rooms		Awakened from sleep
	Faintly	Clearly	
V	23	7	46
B	15	1	10
H	8	1	15
N	8	4	7
S	6	4	23
P	10	2	11
R	2	2	3
M	12	1	10

The respondents were asked to state the causes for being awakened. Findings are shown in table 6, which shows the number of patients awakened by the particular sound. In this table certain sounds might hav been combined with others in a single category, but they have been listed separately to point up outstandin sources of sleep interference resulting from certai conditions or practices in specific hospitals.

From table 6 it is possible to determine which of th indicated sleep-interfering sounds are prevalent in th greatest number of hospitals surveyed, as shown i table 7. Four of the seven sounds are also found i the listing of the most prevalent annoying sounds i tables 3 and 4. Since no general correlations wer found between the replies and the illness, length of stay age, sex, or occupation of the patients, no tabulation have been made involving these factors.

Table 6.—Causes of being awakened

Sound	Hospital							
	V	B	H	N	S	P	R	M
	Number of patients							
Patients' talk, early morning/night	5				1			
Nurses' station noises	2							
Shift changing	2							
Staff talking or walking	6			1		2	2	
Ill patients, other rooms	8	1	1	2				
Ill roommate	7	3						
Recovery room sounds	2							
Bedpan washer	1							
Pantry noise at night	2		1					
Arrival of new patient	1		1					1
Moving equipment	1							
Truck delivery, early morning	1							
Sirens	1			1				
Traffic	1			1				
Lawn sprayers	1							
Shade flapping during storm	1							
Personnel cars arrive or leave, a m , p.m	1				1			
Corridor noise· activity, p m , early a.m	2	2		1				
Floor polishing	2							1
Noise from stairway	1							
Pans or objects dropped or banged	1			1		2		
Roommate noisy or active		2			2			
Ice pitcher service and pick-up, midnight		1						
Babies or children crying		1	2	1				
Auto racetrack			3					

Table 6.—Causes of being awakened—Continued

Sound	Hospital							
	V	B	H	N	S	P	R	M
	Number of patients							
Chart cases	...	...	1	...	...	...	...	...
Elevator doors	...	...	1	...	...	...	...	...
Night emergency	...	...	2	...	...	...	...	...
Carts	...	...	1	...	...	1	...	...
Food service	...	...	1	...	...	...	...	...
Visitors' talk	...	...	1	...	...	...	...	...
Preparation for patient care, early morning	...	...	2	...	...	...	...	...
Telephone	...	...	1	1	...	3	1	...
New roommate admitted	...	...	1	...	...	...	...	...
Unidentified machinery	...	...	1	...	...	...	...	...
Cause not indicated	...	...	...	1	1	...	...	...
Ice water service, 5:30 a.m	...	...	...	...	13	...	...	...
Chair scraping	...	...	...	...	1	...	...	...
Utility room noise	...	...	...	...	1	...	...	...
Kitchen help at elevator, early morning	...	...	...	...	3	...	...	...
Patients in cafeteria line, breakfast	...	...	...	...	1	...	...	...
Door slam	...	...	...	...	1	...	...	...
Bathroom door left open, light switched on/off	...	...	...	...	1	...	...	...
Therapy or oxygen tent equipment, same room	...	...	...	...	...	1	...	1
Cleaning equipment, 5:00 a.m	...	...	...	...	...	...	...	2
Voice paging	...	...	...	...	...	...	...	2
Exhaust fans	...	...	...	...	...	...	...	1
Police or ambulance radios left on	...	...	...	...	...	1	...	...
Delivery room door left open	...	...	...	...	...	1	...	...
Milkman and kitchen help: loud talk	...	...	...	...	...	...	1	...

Table 7.—Sleep-interfering sounds common to several hospitals

Sound	*Number of hospitals*
Other patients in distress	5
Staff talking or walking in corridors	5
Telephone	4
Arrival of new patient	3
Corridor noise and activity, evening or early morning	3
Pans or objects dropped or banged	3
Babies or children crying	3

Discussion of Questionnaire Findings

Table 4 shows that the sounds noted as most annoying are caused by the use of television and radio by other patients. Second, and in fact prevalent in most hospitals, is staff conversation in the halls. In some cases, as evidenced by the comments, this was objected to not because of the noise level but because of the information communicated, such as discussion of other patients, operations, and symptoms. A continuous educational campaign might help to reduce this cause of complaint. Third is the annoyance caused by other patients in distress, moaning, or calling for a nurse. Distress sounds, because of their nature rather than their loudness, are annoying to others.

Although acoustically treated ceilings help to reduce noise, hospital corridors, with their hard walls and floors, conduct sound readily. Noises entering corridors from the rooms that have hard-finished floors are easily transmitted to rooms some distance away. All the sounds listed in table 4, and in fact, the majority listed in the other tables, are corridor-borne.

The most annoying sounds are not necessarily the loudest, as measured with instruments. Rather, it is their frequent repetition or their character which the patients find disturbing. For instance, a metal pan dropped on the floor produces a high sound intensity. This, however, is not nearly as annoying to a patient as other sounds of lower intensity but greater recurrence, such as walking in corridors, rattling carts, paging by voice, or flushing toilets.

The most disturbing sounds which cause patients to awaken are those of high intensity. Consequently, the dropped pan, the shrill telephone bell, the sick patient calling out, and staff noise in corridors become serious causes of disturbance.

Some causes of sleep-interfering sounds could possibly be eliminated by revising many hospital routines. One may question the advisability of delivering ice in metal pitchers to patient rooms at 5:30 in the morning; collecting ice water pitchers from rooms at midnight; polishing floors at 9:30 a.m.; removing cleaning equipment and buckets at 5:00 a.m. from a closet that opens on the corridor. These sounds were specifically mentioned as awakening patients in four hospitals.

Chapter 4

MEASUREMENTS OF NOISE IN HOSPITALS

Recorded graphic measurements were made of the noise in the eight hospitals by standard noise measurement and recording techniques. Since the survey was designed to determine the noise levels that might influence patients' rest, the recordings were made in patient rooms, as well as corridors, and a correlation was drawn of the noise in the two locations. These findings it was felt, would be helpful in the development of noise control programs for hospitals of similar design.

The microphone positions at typical patient room locations selected for the various hospitals are shown by the letter B on the floor plans; the corridor microphone positions are designated by C.

The survey was carried out for 24 hours in two locations of each hospital. Thus, in each hospital a minimum of 48 hours was covered by the survey. Although the equipment operates semiautomatically, it was monitored during the entire time by an engineer who provided maintenance, repaired minor routine breakdowns, and noted significant noise sources as sounds were recorded on the chart. He also toured the floor regularly, observing any significant patient reaction to specific noises and noting particular features of noise sources. Another member of the survey team completely examined the hospital's mechanical facilities and both medical and nonmedical work areas.

UNITS OF MEASUREMENT

Sound measuring instruments detect variations in pressure and indicate the results in decibels. The decibel is not a unit of fixed size but represents a ratio (logarithmically) to a fixed base as a standard. However, pressure alone, expressed in decibels, does not provide an accurate indication of loudness since frequency must also be considered.

Through investigations in the relationship of loudness to frequency and sound pressure by analysis of group responses, two methods of evaluating loudness have been established. The first uses the unit phon, which is a measure of loudness level on a logarithmic basis similar to the decibel scale. The second method is an attempt to establish loudness on an absolute unit base, this unit being known as the sone.

METHOD OF MEASURING NOISE

Instruments do not give a direct reading of loudness. Using either of the above-mentioned evaluation methods, the sound must be divided into bands of one-octave width or smaller and the sound pressure levels then must be determined in decibels for each band. Through an involved mathematical process, it is possible to assign a value of sones or phons to the sound.

This is obviously not a practical method of dealing with complex sounds which continually vary over a long period of time. How, then, might the variations in loudness of background noise and the multitude of individual hospital sounds best be determined?

Standard sound level meters are equipped with weighting networks which attempt to measure electrically the ear characteristics responding to two different intensities, known as the A-scale and B-scale settings. A number of the hospital sounds were analyzed and a general correlation was found to exist between the A-scale values and the loudness level in phons. It may be assumed, therefore, that the A-scale values are a fair representation of the subjective sensation of loudness. A continuous chart recording was made of the A-scale sound level meter readings during each of the two 24-hour periods (app. B, sec. 3, charts 13–20).

TECHNIQUES OF RECORDING

The equipment used to record the sound levels is shown in the photograph and drawing (figs. 14 and 15). The microphone signal was fed to the input of a modified tape recorder. This unit has a step input attenuator and a calibration control to permit its use as a sound level meter when calibrated with a suitable acoustical calibrator. The input of the monitor channel was set to the record position, and the signal of the monitor output was fed to a sound level meter set to the A-scale position. The output of the sound level meter was fed to a graphic recorder. Calibration of the sound level meter and graphic level recorder permitted direct recording of the A-weighted sound level. The chart recorder was operated continuously. The tape recorder was controlled by an electrical timing switch which operated the recorder 45 seconds out of each 3 minutes. A bypass switch permitted manual operation of the recorder when necessary. The tape recorder cycle was limited to alternate half hours. This timing sequence was developed after several trials in industrial and community noise studies. It was verified in the first hospital, where a continuous short-term cycle was maintained for the first 24 hours. Observation of the recording sequence and occurrence of specific noises indicated that the present timing cycle captures all the sounds typical to each hospital. A shorter cycle, tried earlier, was unsatisfactory because it frequently missed major portions of mechanical operating cycles, such as those associated with elevator door operation and refrigerator start-run sequences. A longer cycle was also considered, but the longer wait period between recordings frequently lost important noises.

ANALYSIS TECHNIQUE

At the researcher's laboratory, the first step upon receipt of the magnetic tape recordings and charts from the hospital was to reproduce the tape over a loudspeaker. While this was being done, a technician would identify the sounds on the charts which had been made simultaneously with the recordings. These charts indicated the background noise and all other significant noises through the use of equipment set up as shown in figures 15 and 16. The equipment reproduces the sound levels through an electronic filter which divides the sound spectrum into bands one octave wide so that the level of noise with relation to frequency can be determined. Before recording the octave band charts at the hospitals, a chart record of the A-weighted and overall levels had been made for the various sounds. By repeating the A-weighted level during the recording of the noises at the hospitals, a check was thus provided for the overall calibration of the system.

The levels shown by the chart records were then transcribed to tables, and from the tables the octave band charts in appendix B, section 3 (charts 13–20), were prepared. These charts have been prepared from the background levels and show the overall level, the octave band levels, and the A-weighted level hour-by-hour during both 24-hour periods.

A sample of the original chart recorded in the hospital where the A-weighting was used is shown in figure 17. Also shown is a sample of the analysis of the noise made in the laboratory, a copy of the table including the noise noted in the chart, and a sample octave band chart (fig. 18).

The validity of the success of the techniques employed is borne out by the close correlation between the patient questionnaire results and the characteristics of the noise as described by the octave band charts.

MEASUREMENT RESULTS

Charts 1–10 in appendix B, section 1, show the levels of some of the more annoying noises, as later determined by the questionnaire analysis, with respect to their A-scale values in bedrooms and corridors. As previously noted, the A-scale weighting of the sound level meter through which the recordings were made approximates the loudness level as perceived by the ear.

In reviewing these charts it should be realized that the closer a sound source is to the microphone, the higher the sound level will be indicated on the chart. Also, a given type of sound, such as the clatter of dishes or a dropped pan, will not always register the same level.

For example, chart 1, telephones, shows decibel readings of 56 and 65 for patient room and corridor, respectively, in Hospital V. In Hospital B, however, no telephone bell was noted in the patient room, while a level of 45 db was recorded at the corridor location. In Hospital H, several telephone bells were recorded in each location, ranging from 51 to 60 db in the patient room and from 60 to 71 db in the corridor.

Charts 11 and 12 in appendix B, section 2, show background sound levels by octave bands in the patient rooms and the corridors of the hospitals. The measurements shown were made between the hours of 2:00 a.m. and 3:00 a.m. and represent approximately the lowest noise level achieved in the hospitals.

Charts 13–20 in appendix B, section 3, show a continuous 24-hour record of the background sound levels in each hospital, based on hourly samples.

Charts 21–134 in appendix B, section 4, show specific sounds and average background levels in the various hospitals.

Chart 135 in appendix B, section 5, shows, for purposes of reference, the noise criteria for patient rooms and nurses' stations.

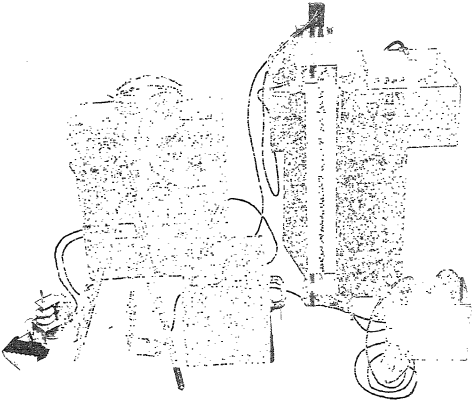


Figure 14. Equipment for reproducing sounds and graphically charting sounds.

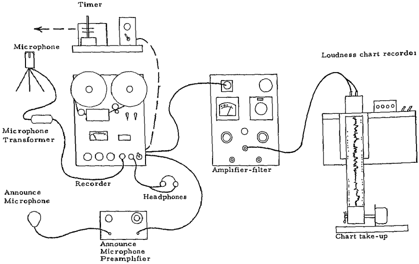


Figure 15. Schematic diagram of noise survey recording set up.

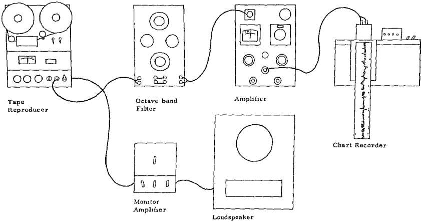
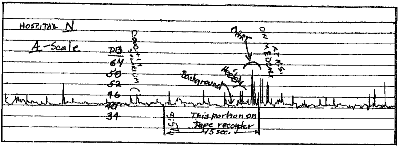
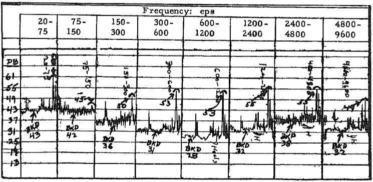


Figure 16. Schematic diagram of noise survey recording analysis set up.

MICROPHONE IN CORRIDOR Hospital N 3:57 A. M.





OCTAVE BAND ANALYSIS

Data Tabulation								
Frequency: cps	20- 75	75- 150	150- 300	300- 600	600- 1200	1200- 2400	2400- 4800	4800- 9600
Background level: db	43	42	36	31	28	32	38	32
Medical cart at Nurses' Station	60	45	50	53	53	55	55	49
Nurse's heels	49	43	42	34	37	41	46	39

Figure 17. Sample of original chart recording taken at 3:57 a.m. showing A-scale chart record, octave band analysis, and tabulation. Upper chart shows sound levels recorded on hospital premises, annotated as to sources of the sounds. Lower chart shows analysis made from concurrent tape recording. Table at bottom shows values tabulated from the analysis. ("cps" refers to cycles per second; "db" to decibels.)

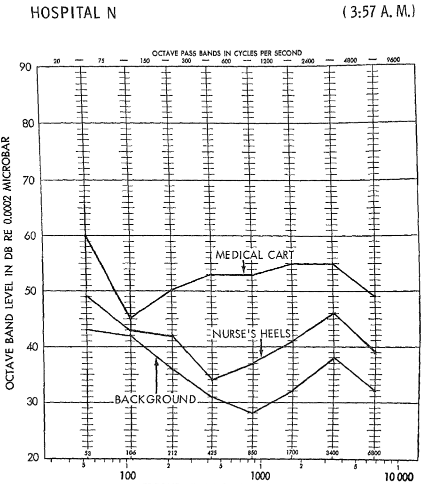


Figure 18. Sample octave band chart showing specific sounds and background sound levels recorded at 3:57 a.m.

Part II

NOISE SOURCES AND CORRECTIVE MEASURES

Chapter 5

CLASSIFICATION OF HOSPITAL INTERIOR NOISE SOURCES

Hospital noises can be divided into two classes—those originating either outside or inside the building. The number of interior noises that bothered the patients far exceeded those from the exterior. Table 2 of chapter 3 lists 61 sounds which disturbed patients. Fifty of these originated within the hospital and the remainder came from outside sources.

Exterior noise sources noted by patients and consultants included street and highway traffic, airplanes, trains, cars and trucks on the hospital grounds or parking lot, people, birds, and crickets. At Hospital H a number of patients were annoyed by sounds from a nearby racetrack where stock car races were held on Saturday nights. Patients complained that these track noises kept them awake beyond midnight. Since the survey was made during the week at this location, these sounds were not recorded.

Respondents noted on their questionnaires that hospital employees sometimes indulged in loud talk and raced their car engines when arriving or departing at night.

To facilitate discussion and reference, the interior sound sources have been grouped as follows:

1. *Mechanical equipment*

   Machinery and equipment, such as boilers and roof ventilators, which operate more or less automatically.

2. *Operational facilities*

   Equipment which is considered part of the structure or permanently in position, such as furnishings, plumbing units, and housekeeping facilities, but which is activated by personnel.

3. *Patient service facilities*

   Equipment, such as oxygen tanks and carrier carts, for direct patient service and care.

4. *Personnel activities*

   Sounds controlled by hospital personnel.

5. *Patients and visitors*

   Sounds originating in actions of patients and/or visitors.

Although there may be some overlapping or differing opinions as to the proper category for a given sound, it was felt that expansion of the above list would be unnecessarily complex.

The majority of the sounds are of mechanical, rather than human origin. For example, many mechanical noises emanate from the boiler room, the air-conditioning equipment room, the elevator equipment space, and all the hospital operational facilities (such as those located in kitchens and utility spaces). These noises could be reduced to a minimum, or eliminated, if care were taken from the standpoint of design and selection of quiet equipment. Unfortunately, mechanical specifications and costs, rather than the elimination of noises, often are the determining factors in the selection of mechanical equipment.

Although mechanical equipment specifications may stipulate "quiet operation," such a description, unsupported by actual measurements, is inadequate for intelligent judgment.

The catch-all phrase, "quiet operation," has appeared in many air-conditioning equipment specifications, but the systems, when built, were still found to be noisy. If the owner complains, costly corrective measures invariably must be applied to such systems. Although it is sometimes possible to obtain quiet mechanical devices for the same price or less than the cost of noisy equipment, in general, the carefully designed, muffled, mechanical devices cost more than their noisy counterparts. No contractor will chance the loss of a contract by including a quiet unit if it is not required. The hospital administrator, the board, and the architect should check all bids and must prevent substitutions of items as "equal" where only a part of the equipment characteristics is equal. Often, noisy fans are substituted for more expensive quiet units. Fans may be equal in air-handling capacity, but will have different noise characteristics. The same precautions should be taken when other pieces of equipment, such as pumps, dishwashers, and refrigeration equipment, are purchased. The low bidder may be low only by virtue of the fact that he has made such substitutions.

The picture is not quite as black as it appears. The use of architectural noise control and vibration isolation techniques can often permit satisfactory use of a moderately noisy piece of equipment. However, no mechanical equipment capable of producing noise should be specified until the architect and engineer are sure that the noise level in the patient areas will be sufficiently low. Methods are available for measuring the noise from existing equipment of the type proposed for use and for determining the noise levels at the various points in the hospital where it is to be installed.

MECHANICAL EQUIPMENT

Boiler Room

The boilers, forced or induced draft fans, intake and exhaust fans, pumps, and automatic valve systems are among the major items capable of making a boiler room the noisiest place in the hospital. A basic solution to the boiler room problem is placement of the equipment in a separate building some distance from the hospital building itself. This solution has merit, but it is not always adequate. In some installations, the intake and exhaust fans and the steam vent lines present a severe problem. Although in such an installation the mechanical vibrations resulting from combustion or caused by pumps and fans are isolated from the hospital, the noises from these sources are still transmitted through the air to the patient rooms. In addition to appropriate silencing devices for the equipment, optimum architectural control of noise in boiler rooms, whether remotely located or an integral part of the building, must be provided. Then the equipment must be selected and appropriate silencing devices added where required.

Boilers

In selecting a boiler for a hospital, the types of combustion equipment manufactured and the noise they produce must be carefully considered. The high-pressure oil-fired boiler is probably the noisiest because of the high-speed blower. However, some low-pressure oil-fired boilers take secondary combustion air through vents or a ring around the burner mechanism. Either of these methods permits direct sound paths for the low frequency combustion noises inside the boiler shell to enter the boiler room, from which the noises are transmitted readily to other parts of the building. These noises are difficult to isolate by the relatively lightweight walls of the boilers, but can be contained by boilers of different design. Some coal-fired boilers use high-speed fans for producing draft. These fans are extremely noisy and can transmit vibration throughout the building unless they are operated close to the optimum point on the fan characteristic and are structurally isolated from the building. Among the quietest boilers are a number of medium capacity, low-pressure gas-fired units. No matter which type of unit is determined to be the most economical, it should also be assessed as to noise potential; a new selection should be made if the unit initially selected will cost more when quieted than the quieter units needing no muffling equipment.

Pumps

Pumps are a second essential element in the boiler room. They can be excessively noisy unless they are well-designed and operate within their ratings for flow and capacity, the lines are kept filled with water, and the pumps are correctly isolated from the building.

Condensate return pumps, particularly, cause severe noises. These units too often are placed on the boiler room floor and connected directly to the piping at the point where it enters the boiler room from a patient area. Use of flexible pipe links, a flexible conduit to the motor, and vibration isolators will effectively reduce the noise transmitted to the building. Many pumps are effective producers of airborne noise, because of design errors, such as incorrect impeller shape, poor blade angle, too much or too little clearance at the throat. These pumps are considerably noisier than well-designed pumps operating at optimum design ratings.

Another noise problem occurs with condensate pumps because they are sometimes allowed to operate dry. This condition arises when controls are incorrectly set. However, a good design minimizes the chances of dry operation at any time. Other pumps used in the boiler room and the mechanical equipment room can cause similar operational problems, but these problems are seldom as serious as those caused by the condensate return pumps.

Circulating pumps, used in the lines that carry heating or cooling water to another part of a building, can create a noise problem if poorly designed. Pressure pulses in the water pass through flexible links and cause the entire length of pipe to radiate a humming sound. The only solution to this problem is to replace the pump with one designed for quiet operation.

Vibration-isolated hangers should be used where pipes are hung from a ceiling that forms the floor of a patient area above. This should be done even where flexible pipe links are used between the pumps and the piping.

Today several pump manufacturers already have considerable data on the sound power output of their pumps when operating at design values. The contractor or supplier should be required to submit noise ratings in terms of octave band levels with the bid, or even before the bid, as part of the engineers' design evaluation of the equipment.

Fans

The intake and exhaust fans often associated with boilers and boiler rooms also tend to operate noisily. The sound output from a fan is easily measured, and for fans of reasonably good design, can be readily estimated to determine how much of the sound will be heard in patient rooms. In general, such fans need some muffling, and either duct lining or sound traps are indicated. The fan casing should be placed on vibration isolators and canvas connections should be used to connect the fan to the ductwork. The placing of a high-speed fan in a hole cut in the wall of the boiler room may lead to other problems. The use of self-actuated louvers or mechanically operated louvers only compounds the difficulties.

Forced and induced draft fans mounted on the boiler or within the breeching not only can transmit vibration to the building but can also cause airborne noise to reach other portions of the building. The vibration problems can be eliminated by careful attention to the vibration isolation of the fan and by the use of proper sleeves to connect the fan into the system. The airborne noise problems can be prevented by use of quiet fans and by providing sufficient isolation between the boiler room and the other areas of the building.

Auxiliary Generators

An auxiliary power generator operated by a diesel or gasoline engine is another facility often built into boiler rooms. The three major noises produced by such equipment result from intake and exhaust, sounds that radiate directly from the engine and housing, and sounds from mechanical vibration transmitted to the building. The exhaust should be ducted through a muffler to the outside. The intake need not be treated, provided the boiler room is satisfactorily isolated for airborne noise. The mechanical vibration can be reduced through the use of vibration-isolated mounting for the equipment.

Piping

Hundreds of feet of pipe connect to the equipment in the boiler room, lead from it, and run throughout the hospital.

Where the pipe interconnects several pumps and the boiler, severe vibration can often build up because of the combination of the mechanical forces resulting from the pump pulsations. This condition can readily be alleviated through the use of suitable pulsation filters or snubbers between each pump and the header. Other pipes that interconnect or lead from mechanical equipment that generates vibration must be supported from wall, floor, or ceiling by means of vibration-isolated hangers. These may be units with a resilient member inserted in a break in the supporting structure, or a felt or rubber lining that isolates the pipe from the hanger. However, the units with the resilient insert between the hanger and the wall are unreliable since they do not provide any isolation between the fastening and the hanger but only between the hanger and wall. The vibration thus continues to be transmitted from the hanger through the fastening (bolt or screw) to the wall.

Another serious noise problem is water hammer in a piping system. Water hammer can originate in valves where pressure is high or can be caused by improperly drained steam lines. This problem could be prevented by operating the system at lower pressures and by careful design and installation to eliminate waterpockets in steam lines. Where these measures are not fully effective, air chambers or hammer arresters should be utilized.

Transformers

Electrical transformers are often placed in vaults in the hospital basement. This is good practice, from both a fire safety and an acoustical point of view. Although noise from transformers was not noted during this survey, experience has shown that in small buildings, such as a 25- or 50-bed hospital, a transformer vault located too close to nursing areas can cause a noise problem. Although transformers are nonrotating devices, they can generate a hum at 120 cps and at some of the lower harmonics of this frequency. This hum results from magnetostrictive forces within the core and casing of the transformer. The transformer housing radiates the sound through the air, and the mounting transmits the sound by means of mechanical vibration throughout the building.

Good design requires that the transformer be placed on simple pads of vibration material, such as cork or preferably cross-ribbed rubber or neoprene pads sized for optimum load. The airborne sound will usually be contained by the construction of the vault. The vault should not be located next to or beneath a patient's room. If another location cannot be provided, a cavity wall or a suspended ceiling should be placed on the room side of the vault. Ventilation louvers for transformer vaults should not open underneath windows of patient rooms. The ease with which the low frequency waves are diffracted from such an opening through an open window above permits relatively high noise levels to be transmitted to the rooms above.

Where transformers are to be located outside the hospital building, they should be selected for quiet operation on the basis of sound level data supplied by the manufacturer, the criteria for hospital noise levels, and the expected background noise level for the particular hospital. Additional noise reduction may be obtained by placing a masonry wall on two or three sides of the transformer nearest the hospital building. The wall should be close to the transformer and 10 percent higher than the height required to intercept the line of sight to the highest point under consideration in the hospital building.

Air-Conditioning Equipment Room

Switchgear, pumps, piping, ducts, fans and blowers, and compressors are located in the mechanical equipment room for the air-conditioning and ventilation systems. All these are sources of noise that can be transmitted throughout the hospital by the ducts and piping.

Switchgear

Noise from switchgear is transmitted to other spaces by mechanical vibration and airborne propagation through walls and openings. Two basic methods can correct the situation—enclose the equipment or mount it on vibration isolators. There is a trend today to flush-mount much of the electrical equipment in walls. This practice often leaves a thin surface between a contactor or relay box and a public or nursing area. The equipment should be fully enclosed in surface-mounted or free-standing cases supported on vibration isolators.

Pumps

The problems associated with pumps and piping and the methods of noise reduction have been discussed in the section on boiler rooms.

Ducts

Ducts, through which fresh air is carried from the outside to the air-conditioning equipment throughout the hospital, also effectively transmit sound from one place to another. The noises from the air-conditioning equipment can travel along the metal wall of the duct or through the airspace of the duct and reach the nursing areas of the hospital and the nurses' station, utility rooms and work areas, and administrative offices. The ducts can also convey sound from one room to another room served by the same duct. Thus, a noise from one patient's room can enter the ventilating duct of the adjacent toilet room, can be transmitted to the toilet room above, below, or adjacent, and then can be radiated into a nearby patient's room. This noise can be particularly distracting when the noise source is an oxygen machine or possibly a patient's bed being adjusted by a nurse during the night.

The basic methods for counteracting air-conditioning noise are simple. Short sections of canvas or other suitable material can be used to provide a break in the path of mechanical vibration. The noise within the duct can then be further reduced, either by using a sound trap or by lining a long section of the duct with acoustical material.

Duct lining is most effective in small ducts of about 12 by 12 inches or less. In larger ducts, lining in combination with lined turns and lined plenums can be effective, but this method must be weighed both economically and mechanically against the use of prefabricated sound traps. The use of lined ducts indicates a higher cost for the duct itself. However, the static pressure of the system is increased little. The prefabricated sound trap usually costs less than an equivalent acoustically lined duct, but because the sound trap creates a higher pressure-loss than a lined duct, its cost should be considered against that of a lined duct. Where space is at a premium, however, a sound trap is the better solution.

Lining is not recommended for ducts that serve areas where asepsis is important, such as operating and delivery rooms, nurseries, and treatment rooms.

Where one duct serves a number of adjoining rooms, the duct should be lined or a trap should be placed between the rooms if there is a possibility that the noise from one room may disturb the occupant of an adjacent room. This recommendation applies to patient-room toilets that are stacked vertically or are alternated with other patient rooms on the same floor.

In one hospital (H) the ventilating duct for the floor kitchen passed through the ceiling and wall of the linen closet. Radiation of the resultant sound through the sidewall of the duct transmitted noise to the floor, particularly in the patient rooms near the linen closet.

Noise in a duct travels against the direction of air flow as readily as it travels in the direction of flow. This fact is often not thoroughly understood. Many times, air-handling systems are treated for sound reduction on the supply side while the return side is left untreated. Noise reaches all the areas served by the air-return duct system. One reason many of these systems are not noisier may be that since return air is frequently drawn through an adjacent toilet room, some sound isolation is provided between the patient rooms that are being exhausted and the fan. The usual practice of using a corridor ceiling as a plenum should not be employed in a hospital system, where conditioned air is to be directly supplied to and exhausted from every room.

Careful analysis should be made of the duct layout to prevent direct transmission of noise from the fans and the transferral of noise from one room to another.

Fans

Fan noise often may be reduced by treating the plenum within which the fan is located. The additional quieting required may then be obtained by treating the ducts or by using sound traps, as described above.

The location of the fan greatly influences the amount of noise that will reach other areas. If the fan is too close to the area supplied, sufficient reduction of the noise in the space between the fan and the first diffuser will be extremely difficult. Even where there is sufficient distance to provide interior quieting, the vibration and noise from the fan may penetrate the duct wall and bypass the duct system completely. To correct this situation, the fan should be mounted on vibration isolation rails (a good general practice), the fan housing should be wrapped with 2 to 4 inches of insulation, and then the duct should be wrapped with expanded metal lath. This should be followed by at least ½ inch of sanded plaster. Metal lugs or other connections should not be placed between the metal lath and the fan casing. This treatment, however, should not be carried over canvas connections. All canvas connections should be located within the fan room, so that the noise which escapes through the connection will not be transmitted throughout the hospital.

Fan noise may be minimized by selecting fans to operate in the optimum region of the fan performance curve, by preventing turbulence within the fan casing (usually caused by incorrect takeoff conditions), and by providing for good maintenance conditions. Fans located in crawl spaces or in furred ceilings will receive considerably less maintenance than those placed within adequately sized, well-lighted fan rooms.

A vital aid to the system designer in selecting quietly operating fans is the increasing practice of fan manufacturers to provide sound output ratings for their equipment.

Compressors

Compressors generate noise by means of their intakes, by radiating the mechanical noise from the compressor shell, by imparting mechanical vibration to the building structure, and by transmitting the vibration along the piping.

As with all the devices discussed above, the compressor should be mounted on vibration isolators in a suitable acoustically isolated space. The intake, if it is air rather than a refrigerant, should be quieted with a duct silencer or a commercial compressor intake silencer. Conduit and piping should have flexible links that permit flexure in three dimensions, and the compressor should be mounted on vibration isolators that provide sufficient deflection to isolate the lowest frequency generated. Maximum transmission permitted should be 5 percent. A value of 1 percent is readily attainable with currently available mounts. Because the noise radiating from the compressor casing is extremely difficult to isolate by means of a housing, the best solution would be to place the compressor as far as possible from the nursing areas. Where this cannot be done, a sound-isolated room consisting of panels having a sound-absorptive facing on the inside should be built for the compressor.

Since any sound that is absorbed before it leaves a room reduces the sound level in other parts of the hospital, acoustical treatment should be provided in the air-conditioning equipment room. A 4-inch-thick glass fiber blanket held in place by metal lath provides low-cost treatment for walls and ceilings. Conventional acoustical roof deck for ceiling treatment and structural building products having high acoustical absorption for wall treatment can satisfactorily reduce the sound power that leaves a mechanical equipment room. Conventional cemented acoustical tile is not particularly effective for the low-frequency sounds that usually occur in equipment rooms. However, most commercial acoustical tile and ceiling board products can be effective when hung in a mechanical suspension system 7 inches or more below the slab above.

Roof Ventilators

In the two hospitals that had all nursing units on a single floor, the noise of roof ventilators was heard at various intensities throughout the night, when the other hospital noises were at a minimum. These roof ventilators were connected to ducts that vented toilets in various patient areas and they are similar to roof ventilators that are used to exhaust air directly from an over-ceiling plenum.

The noise from blowers and fans often varies as the load is changed by the opening and closing of doors in various spaces served by a fan. The change in level and character of noise heard close to the threshold of human hearing can be as disturbing as the sound of water dripping slowly into a sink. These sounds can actually cause a person to expend considerable energy in an effort to hear better or "not to listen" to them. To patients in a hospital, such noises may be undefinable or unidentifiable. However, experience with community noise problems and the reactions of individuals has shown that various noises can provoke extreme annoyance and, in some cases, legal action on the part of physically healthy residents.

Many persons feel that some noises must be tolerated while in a hospital, but this does not mean that every effort should not be made to abate them. The patient's room is one important place where such a start should be made. Correctly installed room ventilators mounted on vibration isolators can operate quietly. Ducted ventilation equipment also can be quieter if the ducts are provided with canvas connections at the fan, the fan speed is low, and the ducts are lined when sound power level calculations indicate that too much sound energy will reach patient rooms or corridors through the doors (when open) of the toilet rooms or other spaces served by the ventilator and duct.

Elevators

Hospital elevators require special features, such as extra door width and elevator depth for accommodating stretchers, fast-acting safety door closing equipment, and doors at both ends or at one side and one end. Actually, hospital elevators must have freight-handling capacities with the safety and speed of passenger elevators.

To accomplish these special purposes, a complex of electrical and mechanical equipment is required. Some of the equipment may be located in an equipment room at the head of the elevator shaft and some may be located on the elevator frame itself.

In the hospitals surveyed, the most prevalent noise associated with elevators was the rumble and thump of the doors opening and closing. Noise from elevator door mechanisms and door closure can be eliminated by careful adjustment of the equipment. Some unusually noisy door-trip mechanisms should be enclosed by sheetmetal housing coated with a mastic compound, such as automobile undercoating. Door closure noise is not eliminated by the rubber-faced safety strips placed at the edge of the elevator doors unless rubber stops also have been placed on the concealed stops above, below, and behind the exposed portions of the doors.

Another elevator noise is caused by the gap at the door threshold. This gap causes carts to be jarred as they are brought into or are removed from the cab. Closer mechanical control of the position of the cab in the shaft is necessary to prevent this. Elevator floors are sometimes grooved for positioning the doors. Such grooves also cause carts to rattle as they are pushed into or out of the cab. The noise is generated whether the cart is loaded or empty. When the cart is loaded with dishes or trash cans, the clatter is even more intense.

Other noises from the elevator system include switchgear noise and motor and brake noise, transmitted both by vibration and through the air to patient areas. The handling of switchgear has been discussed in the section on air-conditioning equipment rooms.

At Hospital H, the sound of the motor operating at low speed while bringing the elevator cab to exact floor level was transmitted through the shaft to the three top floors and through the ventilation ducts to an area around the floor kitchen on the fifth floor. This area included the patient's room adjacent to the kitchen. The problem of elevator motor noise, such as that experienced at this hospital, must be analyzed carefully. Conventional vibration isolators placed under the motor and winch assembly could lead to an unstable system. However, the noise from the motor is predominently 120 cps, which requires small static deflection of isolator material. Thus, a thin cork pad (about 1 inch) under the motor and winch base may provide all the isolation required. Care should be taken to see that ducts from the air-conditioning system do not pass through the elevator equipment room.

Where elevator-room noise is high, an acoustically lined duct may be used to isolate the elevator room from the elevator shaft. The cables can run freely through a 6- by 6-inch box lined with resonant-type absorptive material tuned to 120 cps. In only one of the eight hospitals studied was such a drastic measure needed, but it would have helped considerably.

Most elevator noises are relatively inconspicuous during the normal daytime activity of the hospital. At night, however, and during several periods of comparative quiet during the day, these sounds are sufficiently higher than the background noise to be possible sources of disturbance. Although elevators should operate as quietly as possible, their proper location away from patient rooms, according to good design practice, will assure the elimination of disturbance from this source.

OPERATIONAL FACILITIES

Mechanical Units

Refrigerators

One of the most predominant background noises in all the hospitals was from refrigeration equipment located within or adjacent to the nursing unit. Often a refrigerator for medical supplies was located at a nurses' station near patient rooms. Such a location, an excellent one from a traffic point of view, is made disadvantageous, however, by the loud intermittent noise produced by the mechanical refrigeration equipment. Most refrigerators used for this service were equipped with exposed compressors or compressors located behind lightweight metal panels on the front and sides and open at the back. (Such an arrangement would never be acceptable in a household refrigerator.) In hospitals, these refrigerators are often located within a few feet of patients' doors. Even where such refrigerator units are used in floor kitchens and pantries, they can be annoying because the doors of these areas are often left open.

The refrigerating units at Hospital M were particularly noisy. The reciprocating compressor installed in the lower compartment of the refrigeration cabinets generated a low-frequency sound that could be heard throughout most of the floor. The sound radiated through louvers at the front of the cabinets and through the unenclosed rear openings of the cabinets. This design is contrary to the basic theory of noise control for mechanical equipment.

If a reciprocating compressor is used, it can be placed within a double-walled box and equipped with a sound-isolated inlet duct and a vertical exhaust duct to provide air circulation by convection, thus preventing the noise from spreading throughout the hospital floor.

Vibration isolation of the compressor may be effected by mounting a common base for both the motor and the compressor on spring-type vibration isolators within the cabinet. The comments above apply to both food and medicinal supply refrigerating units. Although the units at hospital M are cited, equipment of this type was noted in all but one or two of the hospitals. In at least one case, the equipment was of stainless steel, undamped, and unsealed at the joints to facilitate cleaning. This type of construction, of course, increased its sound output. There are many economical ways of providing sanitary, sealed refrigeration cabinets with sealed compressors for hospital use, and the noise control features should be specified.

The use of vibration-isolated, sealed compressor units in home refrigeration equipment has been standard for almost 30 years. These units are capable of continuous operation without frequent servicing and provide large capacities, if required. The difference in noise levels would be 10 to 20 decibels and the starting and stopping sounds that are clearly audible in the typical units now in use would be less audible.

The refrigeration compressors used for hospitals must be reliable. Experience with the quiet, sealed refrigeration compressors has shown that they have a long, trouble-free life under wide conditions of use. The coils in this type of compressor, however, should not be covered. When use of sealed refrigeration units is planned, sufficient free space should be allowed around each refrigeration cabinet. The manufacturer's catalog will show the space required, which is often only 3 to 4 inches.

Drinking Fountains

The selection, location, and installation of water coolers are also factors warranting attention in hospital planning. In some hospitals, small office-type water coolers were located conveniently in the corridor or in the facilities core. All these units made noises which were clearly audible during the late evening and early morning hours. In all cases, the noises were intermittent, and the cycling of the compressors could be heard along the entire corridor length. The noise levels were sufficiently high to cause restlessness of patients in nearby rooms. Proper location and installation of water coolers will reduce most of these noise disturbances.

At Hospital B, the water cooling unit built into the wall was relatively quiet, for two major reasons. First, the unit does not have a sheetmetal housing that would radiate sound extensively. Second, the unit was well maintained.

Like other mechanical devices, the packaged water coolers require maintenance, but they seldom receive the necessary attention. This lack of proper maintenance may possibly be caused by the inconvenience of removing the unit for repair, or some other factor. None of the packaged water coolers seen in the hospitals studied were in good repair and operating quietly. On the other hand, the wall unit at Hospital B appears easy to maintain, and it has no large metal surface that radiates sound. It might have been a problem, however, if it had been incorrectly installed or improperly isolated from the walls. Because of the noise problem they present, hospital water coolers should be heavy duty units, quiet, and simple to maintain. The difference in initial cost does not justify using an inexpensive, potentially noisy unit. Although these less expensive cooler-fountain units have been placed into small alcoves in some hospitals, such a location may pose both a maintenance and a cooling problem. There is insufficient escape area for the heat generated in the machinery. This condition, in turn, shortens the life of the equipment and is another factor in favor of the built-in wall units. A remotely located central refrigeration system would effectively alleviate the noise problem in drinking fountains.

Ice Machines

Ice machines were particularly noticeable as causes of noise at Hospitals R and S. The levels were high enough to cause some patients to reach wakefulness during the early morning hours. At Hospital R, the equipment itself was noisy. At Hospital S, the noise came from the sound of the ice processing, that is, the ice could be heard as it dropped into the storage bin. When this bin was emptied into metal containers by hospital personnel, an extremely high noise level was produced which permeated the floor.

Quiet, fully enclosed equipment should be used for ice machines. If the process is noisy, a sound isolating system should be used. If ventilation of the ice machine closet is all that is needed, a few feet of lined duct would be more effective and far quieter than the louvered door that is often used.

Dishwashers

The dishwashing machines pose a set of problems. A portion of the noise here is made by steam that is throttled into the dishwasher during the sterilizing cycle. Water used in the initial part of the cycle for washing and rinsing strikes the metal sides of the dishwasher and generates a sound resembling rain on a tin roof. Added to these two sounds, which are at opposite ends of the pitch scale, is the sound of the electric motor that drives the pump and gear train which controls the cycling of the equipment in the more complex machines. The noises of the pump and gear train are often transmitted by the frame of the machine to the sheetmetal housing from which they are radiated to the surrounding rooms. In some cases, as at Hospital H, they are transmitted to the floor and wall by the supports and then into the adjacent room by the vibration of the wall.

Dishwashers, of course, cannot operate without steam and water. However, it is relatively simple to adjust the steam to pressures low enough so that the steam does not hiss noisily each time the valve opens. The cabinet can also be sealed to reduce the sound and heat output. To reduce the noise radiating from the water spray, the sheetmetal can be made rigid by embossing, and can be fabricated from laminated sheets spotwelded at suitable points and continuously welded at the edges. Lamination, using high-temperature adhesives and continuous welding at the edges, will provide even more damping of the sound. This treatment will also reduce the amount of noise that is radiated from the motor. Another corrective step for quiet operation of the equipment is to place the motor and control mechanism on vibration isolators, providing flexible pipe and conduit as required. These steps should greatly reduce the sound output of the dishwasher. In addition, use of considerable acoustical material in the rooms where these machines are placed, as recommended in chapter 8, will further reduce the noise that reaches patient areas.

Sterilizers, Autoclaves

Central sterilizing rooms preferably should not be located within a nursing unit. It may be possible, however, that a sterilizing room may be located in a core or facilities area near patient rooms. To prevent the mechanical equipment of a sterilizing facility from producing noise that would disturb patients, care should be taken in locating the mechanical equipment room. Where possible, corridor doors should be used to separate the core or facilities areas from the nursing unit. The central sterilizing room at Hospital V was located in a corridor some distance from any patient rooms, but the mechanical equipment was placed in a small closet that opened onto the corridor. The sterilizing room was ventilated through a louver in the door, which permitted the mechanical noise to reach the corridor and, in turn, the patient rooms. Even without the louver, the corridor closet location would have contributed to the patient area noise level unless the door had been gasketed.

The doors to the central sterilizing room should also be given careful attention. Because of the clatter caused by the handling of equipment to be sterilized and the noise made by the operation of the autoclave and other units within the room, provision should be made for keeping the doors closed at all times. The central sterilizing room should include vision panels in the doors, sufficient cabinet and storage space within the room, and, most important of all, adequate ventilation. This room requires extra volumes of air to remove the heat from the equipment and the steam to make the room comfortable. Calculation of the heat load for the sterilizing room, particularly where steam is used, must take into account the extra heat sources within the space.

Plumbing Units

Faucets

The sound of running water is seldom thought of as an annoyance, but it can raise the overall noise level considerably, especially when the water flows from a faucet under high pressure. Depending on the pressure, the shape of the faucet, and the size of the pipe, the noise level caused by running water can vary over a wide range.

In most of the hospitals studied, the sound of running water at the nurses' station was clearly audible in patient rooms. Faucet attachments can be obtained which smooth the turbulent flow and reduce the noise level. The velocity of the water can also be reduced by placing a valve upstream of the faucet.

Another factor contributing to the noise level of running water is the basin into which the water flows. Many hospital basins are fabricated of stainless steel and are large. These metal pans ring loudly when struck lightly by a solid object; they ring similarly when struck by a stream of water. Application of an undercoating-type damping material will not only reduce noise from the water stream, but will reduce the noise made when utility pans and other objects are dropped or placed into the sink.

Defective washers in many faucets produced long, high-pitched squeals when the faucets were turned on or off sharply, or caused a steady dripping which, although soft, was highly annoying. Good maintenance would readily correct this problem.

Toilets

The sound of a flushing toilet can be irritating to many people, as evidenced by annoyance scores in five of the eight hospitals. Silent flushing toilets can be obtained from several manufacturers and should be specified.

Several instances were noted where corridor toilet room doors had ventilating louvers.

Bedpan Washers

Equipment for utility, subutility, and bedpan rooms should be selected for quiet operation. Silencers for clinical sinks and toilet flush valves, as well as sanitizers that are designed to seal continuously at the lip, should be specified. These features, combined with correct steam-pressure settings and suitably sized valves and steam lines, would reduce the undesirable sounds that so often accompany the flushing and sanitizing of bedpans.

Furnishings

Cabinet Doors and Drawers

Routine activities at the nurses' station include preparation and handling of medications, pharmaceuticals, and supplies. These activities are accompanied by the opening and closing of cabinets and drawers in and around the nurses' station.

The problems that occur with cabinet doors and drawers involve a conflict of needs. Doors and drawers that are frictionless and operate with ease will make more noise when pushed shut in a conventional way than a "sticky" drawer or door that must be pushed all the way to closure. The use of ball-bearing slides on drawers and box-framed edges on the hinge side of cabinet doors makes them easy to close with just a slight push. Momentum does the rest.

Conventional hard-rubber bumpers on sheetmetal drawers and doors are not effective. The laws of physics which govern transmission of impact forces show that two light objects separated by a small elastic piece will not provide much energy reduction between the objects. Although the rubber bumpers prevent the sound of metal striking metal, the accompanying thud is not any less intense by using the bumper; only the character of the sound changes.

Because of the ineffectiveness of the use of the conventional hard-rubber bumpers on sheetmetal drawers and doors, another means of reducing noise from this source must be found. The mechanical construction techniques should be analyzed to determine the possibility of placing sound-damping blocks or bumpers at points where the forces will be reduced due to energy absorption (which can be provided by the elastic properties of the bumper and the mass of the cabinet frame). One possible solution would be the installation of spring and slow-acting door closures on the cabinets.

Metal Sinks and Cabinets

Metal sinks and cabinets can be satisfactorily treated with a damping compound to reduce sound radiation when water runs into the sink and doors strike, or are struck by, equipment being removed from or placed in the cabinets. As with the dishwasher, damping can be accomplished by laminating thin sheets of metal directly. Lamination can also be achieved by use of an elastomeric adhesive that can absorb a considerable amount of energy. (The suggestion that the edges be welded is made mainly for sanitary reasons.) A plastic coating compound having properties similar to that of the mastics could be used, followed by a coating of compatible spray plastic finish. This would permit the use of lighter gage metal than is now required, and would considerably reduce the sound output.

Chart Cases and Racks

One of the noises heard continuously in all the hospital corridors and in most of the patient rooms was the opening, closing, and movement of chart cases. The frequent handling of the charts throughout the day by nurses coming on and going off duty, before and after patient medication, as well as by the residents and attending physicians who review and add their notations, results in a constant noisy situation at the nurses' station.

The nurses and doctors do not, or possibly cannot, remove and replace a chart in the rack without striking other charts on the rack. When charts are replaced they are often dropped back into position after being inserted only one-half or one-third of the way in the rack.

These chart cases, in all hospitals but one, are made of aluminum and are hinged at the top. Extension rods at the top permit their suspension in a vertical rack with a series of sloping arms indented at intervals to take the rods on the cases. Many of the chart cases seen had small pieces of rubber or plastic tubing over the rods to minimize noise from the case. However, in the hospitals where these rubber-tipped rods were used, the rubber tipping had come off most of the chart cases inspected. The main source of noise is that of the striking of chart cases against tables, against each other, and against the rack stops.

The noise is readily radiated by the metal case and the table or rack. To reduce or eliminate the noise from this source, the case should be damped by use of sandwich-type construction and a plastic jacket should be molded around the metal case. Other measures include putting wire handles or finger loops on the charts in the rack, and using sloping shelf racks with damped or undercoated shelves.

Vinyl-covered aluminum chart cases with rubber-tipped extension rods for vertical-type racks also are available.

Beds

The metal beds, with a variety of mechanical adjustments and detachable bedrails, are a source of considerable noise in patient rooms. When a patient was admitted the sounds caused while preparing a bed and adjusting it for the patient generated some of the highest impact noises measured in the study. The raising and lowering of beds and the installation or removal of bedrails could be heard throughout most of the floors even when the doors of the rooms were closed. No hospital was free of this kind of noise, which often occurred during the mid-afternoon and late at night. Since both of these times are rest periods, the noise was particularly disturbing. Patient reaction appeared to be similar to that of a well person's response to an alarm clock.

Some of the noise can be reduced at the source by appropriate maintenance measures, including lubrication of the adjustment mechanism. Further noise control can be achieved through the use of inexpensive, replaceable plastic inserts or sleeves on the bedrails. Additional reduction of bed and bedrail noise can be achieved when the patient rooms themselves are acoustically treated.

Bed Curtains

Bed curtains are another source of noise capable of awakening patients. The noise caused while adjusting the curtain have high frequencies and can be described as a "shrill squeal." This results mainly because the runners of travelers on the curtain hooks spin against the curtain rods. Apparently little can be done to remedy this situation. Damping inside the curtain rod with foamed plastic that has a high damping factor is the only feasible suggestion for mechanically controlling such noise. An understanding of the problem on the part of hospital personnel, however, might also solve the problem, since they could effectively aid in controlling this noise source by adjusting the bed curtains more slowly.

Furniture

A sound frequently heard, particularly at night, is the sharp scrape of a chair being moved at the nurses' station. Occasionally furniture is dragged down the corridor from one room to another, creating banging and scraping noises. The moving of chairs during visiting hours also causes excessive noise.

Noise from this source can be quieted by use of acoustical materials in the rooms. Gliders attached to the legs of furniture might improve the condition and, of course, control at the source can be achieved through cooperation of personnel and visitors in the handling of furniture.

Housekeeping Facilities

Vacuum Cleaners

Vacuum cleaners are inherently noisy machines in their present stage of development. Although some quietly operating industrial cleaners are available, they cost more initially. It was noted during the survey, however, that vacuum cleaners generally were used during the daytime, when they would be least disturbing. These factors should be weighed against the purchase of a higher-priced industrial vacuum cleaner.

For reduction of vacuum cleaner noise, consideration should be given to installation of central vacuum systems with plug-in hose outlets.

Floor Polishers and Scrubbers

All the electric floor-polishing or floor-scrubbing machines observed in the survey were inherently noisy. Floor polishers vary in noise output, and this factor warrants consideration when selecting them for use in hospitals.

Appropriate scheduling of the use of the polisher during the day will further reduce the annoyance. In one hospital, the floor polishers were used at 5:00 a.m.

In two others, patients complained of floor polishers being used at night after 9:00 p.m. Such maintenance practices should be scheduled for a more appropriate time.

Cleaning Equipment

Metal scrub buckets and trash containers, with their clanking sounds, also cause offensive noises when handled improperly. Rubber rings on the bottoms of pails and damping material on trash containers would help to reduce the noise, as would the use of plastic containers, where feasible.

Communications

Voice Paging

This form of communication can become annoying depending on the frequency of calls, the setting of the amplifier, and the voice quality of the person speaking. At four of the hospitals, the voice-paging systems produced levels considerably above the background noise levels in both the rooms and corridors. At Hospital N the voice-paging system was adjusted to a noise level close to that of the background noise. The other hospitals did not use voice-paging systems.

The noise source of voice-paging systems, including the selective radio-paging units is obvious. These systems can be operated at low levels, as at Hospital N, but the use of low-level paging requires training and cooperation on the part of operators and staff.

Two important facts shown by the survey are that the paging system can be an annoying source of noise capable of waking patients and that voice-paging systems can be operated quietly. Simple level-control adjustments and staff cooperation could eliminate the annoyance where voice-paging systems are installed.

Telephone Bells

Telephone bells were found to be annoying in all the hospitals surveyed (table 3). The degree of annoyance caused is indicated by a seventh-place rank-order in the list of annoying sounds of all types (table 4). Telephone bells are the third most prevalent noise causing patients to awaken.

In several of the hospitals, night switchboard connections placed all the incoming calls on telephones at the nurses' stations. Thus, at a time when patients need quiet, an operational procedure added noise.

Telephone bells are intentionally made to be shrill and insistent. However, the telephone company can furnish less intense signalling devices. Among these are quieter (damped) bells, low-frequency buzzers that are not as startling as the conventional high-pitched bells, a musical gong, and call lights.

Patients' Call Buzzers

These signals are generally strident and piercing. When not responded to immediately, some patients tend to keep up an insistent buzzing to the annoyance of others on the floor. The sound output of the buzzers should be adjusted to the lowest practical level.

A more acoustically satisfactory system, noted in some hospitals, is the room indicator light used in conjunction with a single musical chime.

Handbells

The handbells used by patients in oxygen tents seemed to annoy a few patients in some of the hospitals. However, the handbells are not especially loud or frequent and should not be considered a major noise annoyance.

PATIENT SERVICE FACILITIES

Carts

One of the most frequent noise sources at all hospitals, and one which bothered patients in six out of the eight studied, was the cart. Whether it was a food, medication, linen, or trash cart, it was capable of making noise.

There are four primary mechanisms by which a cart generates noise:

1. The empty cart rattles as it is pulled over uneven floors or door sills.
2. The cart, loaded or empty, rattles because the wheels operate loosely, imparting sharp vertical forces to the legs in a random fashion.
3. The cart, loaded, radiates the noise made by rattling of the load, (glassware, trays, pans, and similar items).
4. The cart, loaded or empty, rattles because loose wheels cause tipping and jolting.

Examination of carts in the hospitals indicated that carts with larger wheels made less noise than any others. However, even these carts were noisy when poorly maintained. To prove this point, a member of the survey team tightened the wheel fastenings on a medication cart halfway along its trip down the corridor, with the result that the remainder of the trip was almost silent. Better design selection and continuous maintenance are the indicated remedies for reducing cart noise originating at the wheels. At Hospital B, quiet, large-wheeled rolling stretchers were often used at night instead of small medication carts. In most hospitals carts used for flowers and "hospitality" purposes were found to be particularly noisy, because of lack of wheel maintenance.

Food service carts, when in motion and when being loaded and unloaded, radiate the clattering noises of dishes, silverware, and trays. High noise levels are especially generated when the empty dishes and trays are returned to the cart—particularly when not handled gently. No annoyance score was indicated for dish and tray clatter at Hospital B, which, for economic reasons, uses disposable paper plates and cups.

The medication, pan, waterglass, and ice carts similarly have noise-producing loads that shake and rattle when the cart is in motion and generate impact noises when the items are moved or placed on the cart. This type of noise could be alleviated by undercoating the tops of the carts with mastic and by fabricating them with a sound-damping welded sandwich construction. The tops of waterglass and pitcher carts should be shaped so that the items being transported would be separated to avoid striking against each other. An alternate method would be the use of a polyethylene tray with depressions to hold glasses, pitchers, or medicine bottles, that could be placed on top of the metal cart. This tray is chemically resistant, replaceable, inexpensive, and can be readily cleaned.

Metal Pans

One of the most startling hospital noises is the clang of a metal pan accidentally dropped, particularly at night. Such accidents seem to happen frequently. Here again, care in handling the equipment is an important factor in the generation or control of noise.

No material other than metal appears to be satisfactory for use as a bedpan or utility pan. However, some studies in industrial noise control indicate that the sound output can be considerably reduced by using two layers of metal spotwelded together with or without a glass fiber sheet in between. Also, with continuous edge welding, a quieter sanitary pan or basin would be possible. Plastic bedpans are available, but as yet have not been found to be generally acceptable.

Oxygen Tent Equipment

Sounds from this equipment generally raise noise levels significantly. At Hospital P, the noise of a portable oxygen machine, and at times, two, dominated the area. This noise is caused by a pump and regulator system combined with the hissing sound of the throttling of the gas.

Oxygen Tanks and Carriers

An additional noise was generated periodically when the oxygen supply was changed. A full tank was wheeled noisily down the corridor, and the empty tank wheeled noisily back. The noise levels were not as extreme as those from a door alarm, but the duration was considerably longer than other sounds of the same level.

The current practice of piping oxygen into the rooms from a central outside storage area solves the noise problems as well as those of handling the tanks. It eliminates the need for wheeling tanks inside the hospital and it reduces the handling of tanks to a minimum. An acoustically treated masonry barrier wall or shed will practically eliminate noise when tanks are changed at the outside location.

Instrument Cases

Noise from instrument cases rattling on carts was noted from time to time in several of the hospitals. This is a noise source which appears to warrant attention by the hospital purchasing agent and manufacturer. The rattle of an instrument case is a particularly disturbing noise. Such noise may be reduced by jacketing the case in soft plastic or furnishing it with neoprene spot-type-deadener bumpers. At Hospital H the noise from this source was spread throughout the floor as a cart with one or two blood-pressure instruments was wheeled down the corridor past all the patient rooms and then back again a short time later. The noise could have been eliminated if the staff member had carried these light, small devices in his hand.

PERSONNEL ACTIVITIES

Nonmechanical sounds which are under the control of hospital personnel are included in this category. Many of these sounds can be minimized through personnel educational programs or changes in operational routine. The chief sources of such annoying sounds are:

Staff Talk in Corridors

Corridor conversation of personnel leads the list of annoying sounds in this category, achieving annoyance scores in all hospitals surveyed. Specific complaints were received from two hospitals regarding doctors' discussions of patients and their symptoms.

Walking in Corridors

Although this particular source of annoying sound stems mainly from visitors, a number of instances were observed where hospital personnel were at fault. Volunteer aides taking care of flowers or hospitality carts frequently wore high-heeled shoes. Visiting doctors often wore shoes with hard heels. Another source of offensive noise occasionally encountered was the "ripple-soled" shoe which, although made of rubber, produced a loud, creaking sound on the hard corridor floors.

Noise on Stairways

Most hospital stairways are highly reverberant and magnify any sounds made in the space. Much of the stair traffic involves staff members, some of whom apparently do not realize the amount of sound from footfalls and conversation that can be transmitted to the nursing area. In the hospitals surveyed, the stairway doors were equipped with slow-acting door closers, so that the doors were ineffective as sound barriers because of the delayed time in closing.

Hospital Routine

Included here are sounds which might be alleviated by a change in routine schedules and exercise of more consideration. The noisy handling of ice-water pitchers by personnel at hours when patients were asleep occurred in two hospitals. Excessive noise and talking in the pantry, kitchen, or utility rooms occurred in several others. The clatter of dishes and the conversation of night-duty nurses during coffee breaks was particularly prominent.

In one hospital, the door to the delivery room area was left open, and the sound emanating from there caused feelings of apprehension on the part of at least one expectant mother.

Housekeeping and Maintenance Staff Talk

At times the personnel in this group apparently forget they are working in a hospital and carry on shouted conversations. The housekeeping and maintenance staffs are usually more concerned with getting their jobs finished quickly than with conscious efforts to avoid noise that occurs while they are handling equipment. An indoctrination program, stressing care in handling mops, pails, trash carts, and mechanical equipment, can alert these personnel to the noise caused during their work and help to decrease much unnecessary noise.

PATIENTS AND VISITORS

The sounds originated by or under the control of patients or their visitors are among the most difficult of all categories to control. During visiting hours at some hospitals one might think the hospitals were resort hotels, judging by the noise generated in corridors and rooms. Despite various admonitory signs and posters requesting quiet, people are inclined to forget that there may be patients who are trying to sleep or rest during visiting hours. Among the sounds in this category found to be annoying are:

Radio and Television Sets

These head the list of annoying sounds, as determined from the patient questionnaire survey. Many reasons may account for a person's reaction of annoyance to sound from these sets. Such annoyance, of course, generally is not due only to the sound level factor. However, much of the noise from these sets in patient rooms could be reduced by one or more simple steps:

1. Acoustical treatment of patient rooms. (See ch. 8.)
2. Modification of sets, using an external, front-facing loudspeaker. (Most table and portable television sets have speakers on the side. This causes the listener to set the volume higher than if the loudspeaker faced forward.)
3. Permitting the use of earphones or pillow loudspeakers only.

The most satisfactory immediate solution to the radio and television noise problem, of course, is cooperation from the listener or viewer. An administrative communication, such as a card or letter distributed to all patients requesting cooperation and indicating the severity of the problem, would probably reduce most of the noise from these sources. However, a permanent solution should be effected. Recommendation 3 above would be the best.

Patients in Distress

Patients moaning in pain or coming out of an anesthetic, calling for a nurse, and children crying place this group high on the list of annoyances. The actual sound levels may not be high, but their nature has decided empathic effects on other patients.

Visitors' Talk in Corridors and Other Rooms

Many visitors either do not seem to understand how well sounds carry in hospitals or are just thoughtless. The same persons probably would not talk above a whisper in a public library. From one or two hospitals, comments were received about visitors who lingered in the halls after visiting hours.

Walking in Corridors

High heels are particularly noisy in the hard-floored, resonant corridors.

Noisy Patients

This group of sounds includes nondistress sounds made by other patients, such as talking together loudly, discussing their operations, snoring, or talking in their sleep.

Part III

DESIGN, CONSTRUCTION, AND FUNCTIONAL CONSIDERATIONS

Chapter 6

EFFECT OF EXTERIOR NOISE SOURCES ON PLANNING, SITE, AND FORM OF BUILDING

The effect of exterior noise on patients must be considered in the selection of a hospital site, particularly in relation to nearby traffic patterns. At three hospitals during this study, it was noted that noise from the local truck routes contributed greatly to the interior noise levels. At hospital M, the nearby trains also contributed to the noise level. The building shapes of Hospitals M and N exposed a maximum number of patients to the noise from the traffic routes. Had Hospital M been oriented 180° from its present location or had Hospital N had a T-shaped plan, with the head facing the street and the stem perpendicular to the street and shielded from it by the head, the situation would have been improved considerably. In both hospitals, with the above suggested plan, it might also have been possible to shield patient rooms from the highway or train noise by locating the offices and facilities other than nursing units on the exposed face of the building. Since the effect of noise is an important one from the viewpoint of providing optimum restful conditions for patients, the orientation of the building on the site and the basic form of the building should be thoroughly analyzed. Other considerations for site requirements and selection would include sunlight exposure, zoning, maximum floor space on a given site, access to location, overall design, and layout.

The basic possible forms include thin rectangular buildings, L- and T-shaped buildings, and buildings with partial or fully closed courts. Any of these forms may be used for single-story or multistory buildings. Some modifications of these forms have been used in the hospitals studied, including the Y shape of Hospital N, and the multiple-wing structure of Hospital B. These forms have many interesting acoustical effects and can influence both exterior and interior noise levels. The multistory building has a number of advantages from the standpoint of noise control. The most important, of course, is the ability to limit the number of noise sources on any one floor.

Driveways and Loading Platforms

At only one hospital in this survey (Hospital B) was it possible for ambulances and other emergency vehicles to arrive at night without waking or disturbing all the patients on one side of the hospital. The same situation exists with regard to early morning deliveries of supplies. At Hospital B, the nursing units are sufficiently far removed from the emergency wing and the service delivery so that emergency and commercial delivery activities are unnoticed by patients.

At six hospitals, the loading and emergency platforms were located on an inside court underneath a large number of patient rooms. None of the hospitals studied had an interior loading dock where the noises from milk deliveries at 5:00 a.m., or the mid-afternoon deliveries of oxygen tanks with their associated high noise levels, could be confined and screened from the patient areas.

Arrangement of Areas

There are a number of conflicting requirements for interior spaces as far as the control of noise is concerned. If the building has a utility core and patient rooms on radiating corridors, effective acoustical treatment of the corridors can provide for quiet rooms at the far ends of the corridors; that is, the noises from the nurses' station, utility rooms, floor kitchen, and elevator will be greatly reduced by the time they reach the end of the corridor.

Long corridors seem to cause increased corridor traffic and seem to be conducive to more conversation between staff members at various places in the corridors in addition to shouting by personnel. A long corridor also requires moving of medical and meal trays over greater distances. When food carts or trays are moved from door to door, an extremely noisy service activity is brought directly to the doors of several patient rooms. Furthermore, patients are exposed to noise from floor polishers and vacuum cleaners for a longer time each day as well as to the noises from other patients.

The use of short corridors radiating in several directions from a central core eliminates the traffic problems but places all the patient rooms close to the many noise sources found in the facilities at the core. Another undesirable feature of the radiating-corridor plan is that noise from one corridor is readily transmitted to the rooms in all the other corridors.

Corridor layout requires considerable attention. In planning corridors with rooms on both sides, doors to patient rooms should not face each other directly across the halls, and should not be placed opposite the kitchen or utility rooms where the noises of pumps or washers will be readily audible every time the door to a workroom is opened (assuming it is kept closed). Even where the doors to patient rooms do not directly face each other, noises from one patient's room can readily travel to the next room by reflection from the smooth wall of the corridor. Transmission of such noise can be reduced, however, by the use of appropriate acoustical materials. In corridors with rooms on one side only, the length of the reflection path is approximately twice that for the direct staggered path between facing doors on a corridor having rooms on both sides.

Although by placing rooms on one side of a corridor the noise level in patient rooms may be reduced, other factors, such as extensive walking distances for the staff, may make it less desirable than a layout with rooms on both sides of a corridor. However, a double corridor arrangement, with patient rooms on one side of each corridor and service facilities between the corridors, is becoming more popular for large nursing units.

CONSIDERATIONS FOR PLANNING

Buildings with closed courts are not particularly desirable because the sounds from patient rooms, utility rooms, preparation rooms, and mechanical equipment spaces are transmitted across and around the court to all other rooms on the court. Hospitals with open courts and the wings at various angles, such as the Y-shaped Hospital N or the V-shaped nursing wings at Hospital B, provide the least opportunity for sound to be transmitted between the various spaces. They also prevent the build-up of sound energy by the reflection that occurs when the wings are parallel and on opposite sides of a court.

Central air conditioning with sealed windows can greatly reduce the problem of noise transmission across courts as well as of other exterior sounds, such as traffic, airplanes, and deliveries. However, none of the eight hospitals had complete central air-conditioning units. Window-mounted air-conditioning units do not exclude exterior sounds but allow them to pass rather freely into the interior.

Important factors that should be considered in planning the utilization of the site, form, and plan of the buildings are listed below.

1. Distance reduces noise; therefore, placing the hospitals as far as possible from the local exterior noise sources may prevent noise problems. The apparent loudness of a sound will be reduced by about one-half if the listener moves away from it to a position three times his original distance from the source. If he moves only a short distance, such as less than half his original distance, there will be little effect on the loudness of the sound.
2. Other buildings belonging to the institution (such as nurses' residence, power house) may be used as sound barriers to shield the patient areas from such noise sources as access driveways, nearby truck routes, or bus routes. These buildings must be within the line of sight between the window under consideration and the location of the noise sources. The same technique is also satisfactory to shield hospital patient rooms from commercial noise sources such as gasoline stations with their pumps, compressors, and automobile engine and brake testing; and from the cooling towers increasingly being used on top of small commercial buildings.
3. Large, high buildings nearby can reflect to the patient rooms noise from railroads or highways, otherwise screened from the hospital. This is particularly important where train noise is the source under consideration. This is one of the problems of the multiple-wing building because the wings may reflect exterior noises into an adjacent wing.
4. Highway grades have a considerable influence on the amount of noise generated by passing truck traffic. An on-site examination of highway activity will show whether trucks shift into low gear, race their engines, or otherwise make excessive noise in passing the proposed site. Truck noise should not be underestimated. It showed up fre-

quently and regularly as the highest exterior noise source at most of the hospitals studied.

5. Vehicular traffic patterns must be carefully studied when considering site location. Traffic lights located near the proposed site create another noise problem, which can be particularly severe if the road is a truck route. Trucks and automobiles starting up after a traffic light or trucks shifting or accelerating to avoid a traffic light change, were additional sources of noise at Hospital V. Switching the traffic light to a flashing signal at night may alleviate the problem but would not eliminate it. A cooperative study of traffic patterns and light sequences, made with the local police or traffic authorities, might be helpful in site selection.
6. The general volume of highway, air, rail, and ship or boat traffic, if nearby, should be examined and the peak hours noted. Although airplane noise did not prove significant at any of the hospitals studied, railroad traffic in the vicinity of Hospital M proved to be a major noise source that disturbed patients, and pleasure-boat traffic on the river adjacent to Hospital P was sufficiently noisy to awaken patients on the river side of the building.
7. Although the choice of building plan is basically an architectural one, the factors pointed out above show the importance of keeping the corridors reasonably short and the doors in a staggered arrangement. Furthermore, the number of wings and the number of floors influence the noise levels in the patient rooms.
8. Because of mechanical noise isolation problems, it may be considered best to place the mechanical plant in a separate building or wing. Such a wing or building can also be used to screen certain patient room areas from a local off-site noise source and should be considered in planning the hospital. This consideration might make the difference between having the unit for this purpose separate, attached, or in the hospital building.

Chapter 7

HOSPITAL NURSING FACILITIES

The basic architectural design of a hospital, as indicated in the preceding chapter, has considerable influence on the noise levels in the patient rooms. The effects of site utilization and building configuration also were discussed in some detail. Other elements of the overall architectural design that influence the generation, spread, or control of noise include: (1) Location and isolation of the nurses' station, utility and subutility rooms, floor kitchens and pantries, linen closets, patients' toilets, elevators, receiving platforms, mechanical equipment; (2) space allocation to nonmedical uses; and (3) types of interior finishes.

Materials and the location and quieting of mechanical facilities are dealt with in separate chapters. This chapter is concerned with the basic planning and architectural features of the nursing area that contribute to the generation, transmission, and control of noise as noted at the hospitals surveyed. The locations of the various facilities and storage spaces influence not only where and when noises are generated, but to a great degree, the control of traffic patterns. These patterns determine where and when aides, nurses, and doctors will be working and talking while patients are resting or sleeping.

Traffic Patterns

At Hospital V, second floor traffic was almost continuous during the day between the nurses' station, patient rooms, the pantry, the supply closet, the bedpan room, the utility room, with some activity at the linen closet. The plan shows that such traffic takes personnel past a larger number of rooms than would be necessary if the pantry, utility room, and supply closet had been grouped around the nurses' station, with all doors in the same area. The worst traffic here was at mealtime, with practically all traffic originating and terminating at the pantry.

At Hospital H, similar problems existed, although not as severe, since the facilities are close together in the center of the north side of the corridor. Patients in four rooms, however, were exposed directly to the noise from traffic between the various facilities.

The long corridors at Hospital M created considerable general traffic, but the use of a central core for the nurses' station, major facilities, and supplies reduced corridor traffic past patient rooms. In fact, this hospital could be considered relatively quiet from the standpoint of floor traffic noise.

Hospital N also has a central core for the nurses' station and other facilities, which limits traffic to that required to handle patient rooms in each wing. However, other planning problems were apparent, such as location of the doors to the subutility rooms which were opposite the doors to the two 4-bed wards.

At Hospital R, the small number of rooms and the compact core arrangement of facilities served to minimize unnecessary traffic outside the core.

At Hospital B, patient wing space was not assigned to any operational facility. This arrangement also minimized the traffic in patient areas and produced optimum corridor traffic conditions.

The plan of Hospital S with its large wards and small number of private rooms created a different situation. The high density of traffic along the main corridor made this corridor extremely noisy for the few patient rooms along it. The wing corridors were relatively free of workrooms, except for the pantries, which did not create a severe traffic problem. The pantries, however, did raise the noise levels in the wings as a result of dish, utensil, and washer noises.

Utility Rooms

Utility rooms and subutility rooms were noisy areas most noticed by patients in all the hospitals studied. These rooms, in general, have glazed-tile surfaces from floor to ceiling, a glazed-tile or cement-finished floor, and a hard plaster ceiling. Few other materials amplify and propogate sound to the extent that these do.

Also, because of the equipment and the activities in the utility rooms, these areas are filled with numerous noise sources.

The first step in a noise control program for these areas would be to reduce the noise at the source. The next step would be to treat these rooms with acoustical materials. In the utility rooms there are a few particularly troublesome noise sources, such as the steam sterilizers and large sinks. The sounds of the water from the clinical sink and the steam from the bedpan sanitizer have levels that are well above the background levels in many of the patient rooms located some distance from the utility rooms.

Even with only partial quieting of the equipment, however, the complementary use of acoustical material in the rooms will result in a considerable reduction in noise levels. To effect such a reduction, the ceiling and upper walls of the utility rooms should be treated with a highly efficient acoustical material. In the past, the specifications for materials for this service have been difficult to meet. The result has often been that acoustical treatment has been omitted from these rooms. The major difficulty lies in obtaining a material that is capable of withstanding high temperature and humidity, will not harbor bacteria, and can be easily washed. Only a few materials with acoustical properties that meet these requirements are available. If the demand increases for such materials, however, manufacturers will expand their production to meet specifications, and others will include such materials in their lines.

In several of the hospitals studied, the doors to utility rooms opened from the corridors into passages leading to the rooms. In others, the door opened directly to a crowded room. In either case, a nurse carrying equipment or trays finds it inconvenient to try to open a door to enter or leave a room. This situation is slightly improved where swinging doors are used. The nurses solve this problem by using door stops or some other means to keep the doors open, which, of course, permits the sounds to enter the corridor. Even an ordinary flush door in a frame with poorly fitted stops would provide a sizable reduction in noise level in the adjacent areas. Correctly placed doors, equipped with rubber gasketed stops, would be extremely effective in controlling the spread of noise from the utility rooms. Where doors cannot be placed for convenient use, they may be left open except for special times, but the frequently used passage that connects the utility room to the nursing unit corridor must be treated with a highly efficient acoustical material on both the ceiling and the upper walls. This is not as effective as a door, but it helps to reduce excessive noises from utility rooms.

FLOOR KITCHENS

The floor kitchens are serious sources of noise in those hospitals where they are located within the nursing unit. At four of the hospitals surveyed, the noises of dishwashing were audible throughout most of the floor and were well above the background in the corridor locations and in the rooms studied. The noises caused during the preparation of trays, handling of dishes and utensils, and the operation of the refrigerator and freezer were transmitted throughout the nursing units. At one hospital the need for ventilation was met by opening the kitchen door during cleanup. This greatly increased the propagation of noise throughout the floor, from the mechanical equipment as well as from the handling of dishes and utensils.

At the other four hospitals, the food was brought to the patient rooms, or within close proximity, on a portable rack or food cabinet and was distributed and collected in the corridor. The soiled dishes and utensils were then returned to a central main kitchen where they were washed. This method also has a few drawbacks. The major problem is the noise created by the handling of the dishes and silverware in the corridor. In all the hospitals, except two, the noise levels rose both before and after mealtime because of the food service and cleanup.

In those hospitals where dishwashing was done in the floor kitchen, the cleanup noise continued for a considerably longer time than would be required to pick up the trays and load them into a cart to take them off the floor.

The solution appears to lie in the optimum location and correct design of the floor kitchens as well as careful planning of the feeding program and continuous careful supervision.

A well-designed floor kitchen should have ventilation adequate for handling the heat and steam from the dishwashing equipment, the heat from the refrigeration equipment, and the heat of lighting so that personnel can work confortably without resorting to an open door. Both the fresh air and the exhaust air should be ducted. In several hospitals, the use of louvered doors to floor kitchens permitted air to be supplied or exhausted, but such doors also allowed noise to escape into the corridors where it was then transmitted to patient rooms. Therefore, doors to kitchens should not be louvered. (This is also a Hill-Burton requirement, for fire safety reasons.) They should be solid-core flush doors equipped with a gasket at head and jamb and a narrow gap at the sill. It might be desirable in some instances to use a threshold seal at the sill.

The mechanical equipment in the kitchens should operate quietly and should be installed in a manner that will prevent it from transmitting noise to patient rooms. Pipes and mounting brackets for equipment should be isolated by means of resilient hangers and, if necessary, flexible sections of piping from the building structure. At two hospitals, the method of installation of the dishwasher amplified the mechanical noise from the machine. At four hospitals, the noise from refrigeration equipment in the floor kitchens was audible in several rooms on both sides of the kitchens.

The remedy is twofold. First, the kitchens should be located as far as possible from the patient rooms, provided this does not create undesirable traffic problems. Second, the equipment for kitchens should be selected not only on the basis of mechanical specifications and cost but also with a view toward noise control.

In several of the hospitals studied, floor kitchens were located on the corridor of the nursing unit, with the doorway at the corridor. In one case, the door faced that of a patient room, and the noise levels in the room were almost as high as in the floor kitchen. In another hospital, the floor kitchen was adjacent to a patient room and had the dishwasher against the wall shared with the patient room. The arrangement of this patient room made it necessary for the patient to have his head near the kitchen wall. This was barely tolerable for the patient. Space adjacent to a floor kitchen might be planned for some other use (for instance, a treatment room, a storage room, or a linen closet) instead of a patient room, thus providing isolation for the patient room.

Where a kitchen must be placed next to a patient room, the use of a double-wall partition is imperative. These double-wall partitions should have a minimum airspace of 2 inches between each wall, which should consist of the same materials used to fabricate other walls between rooms, except that both of the interior faces cannot be plastered. Typical constructions would make use of two 4-inch gypsum-block walls plastered to a ¾-inch thickness on both outside faces, with a 2-inch airspace between the parallel gypsum-block walls.

One practical suggestion for use of the wall between a patient room and the kitchen would be to use it for a pipe chase, provided the wall on the patient room side is carefully sealed and all piping is hung from the kitchen-wall side or supported from the floor. Resilient hangers should be used for all piping, and all openings into the chase should be sealed off from the kitchen with a nonheardening mastic or glass-fiber packing material.

A feasible plan for hospitals with short radiating corridors, such as in Hospital B, results from the use of food cabinet carts. With this system, the kitchen need not be located in the nursing area, thus eliminating its noise problem. The food cart is brought to the corridor junction, and the trays are carried by hand to the patient rooms. The slight increase in the corridor traffic thus created is tolerable, particularly at mealtimes.

NURSES' STATIONS

The major source of noise that had the highest continuous level in the hospitals studied was the nurses' station. However, the different architectural treatment of the nurses' stations at the various hospitals created wide variations in the noise levels in the patient rooms. At Hospital V, the nurses' stations on both the medical and surgical nursing floors were located at exposed interior-corner corridors. At Hospitals M and N, the location was at the junction of the wing corridors. In these hospitals, the noise from the nurses' stations was clearly heard throughout the corridor and in the patient rooms.

At Hospitals P and S, the nurses' stations were in an exterior corner. At Hospital P, the area was screened by a partition but had an open doorway. It also was adjacent to the patient rooms, so that insufficient distance was provided for obtaining sound isolation by means of acoustical materials or distance. The telephone bells at the station could be clearly heard throughout the wing. At Hospital S, each nurses' station was in a separate room which had a door opening on the corridor. Although the noise in the corridor from the nurses' station was considerably less than in other hospitals, in this particular hospital the noise from other sources, such as that caused by the traffic patterns, was quite severe.

The nurses' stations at Hospital H were set into the corridors in a facilities area. Although this situation appeared to be better than the locations at Hospitals M, N, or V, it did not result in much diminution of the noise. A slightly different arrangement used at Hospital R did result in less noise at patient rooms from the nurses' station, but created new problems. The nurses' station at this hospital was at the entrance corner and was enclosed with a high, metal and glass office-type partition. The use of such an enclosure, in combination with acoustical materials, did result in some control of noise from this busy area. However, the door to the nurses' station was constantly being used and could not be closed easily without a banging sound. This, of course, substituted one impact noise every few minutes for the continuous noise of the nurses' station.

The most effective solution to minimize noise from the nurses' station was found at Hospital B. The nurses' station was located at the intersection of the corridors leading to the patient room wings. One nurses' station served both wings, as may be seen from the floor plan (fig. 3). This station was open except for the medical preparation area, which was partially enclosed and acoustically treated. As a result, this hospital had minimal nurses' station noise in any of the patient rooms. Another nurses' facility, however, did contribute to patient room noise. That was the nurses' lounge and dressing room. Noise was generated by the banging and slamming of the door to this room, which could have been prevented by a suitable door closer and rubber stop. The location of the room and its door appeared to make it difficult for nurses to enter or leave and to close the door quietly.

Based on the noise level studies and the review of the physical and architectural needs, it is recommended that nurses' stations:

1. Be located a moderate distance from the nearest patient bedroom.
2. Be fully enclosed, with metal and glass office-type partitions as a minimum, and with plaster and fixed glazing desirable.
3. Have doors located at each end and a small open window area for ease in conversing with visitors and ambulatory patients.
4. Be treated with an efficient acoustical material on the ceiling as well as large wall areas.
5. Have the noisiest activities located away from the windows or doors.

Several other factors are involved in the acoustical design of nurses' stations. Some are mentioned elsewhere in this report and include the relation of other rooms and facilities to the nurses' stations, and the design, selection, and methods of installing cabinets, communication equipment, plumbing, and other mechanical equipment.

Chapter 8

OPERATIONAL FEATURES

LOCATION OF MECHANICAL FACILITIES

A group of operational facilities that must be distributed throughout the hospital comprise the mechanical and plumbing equipment. These include elevators, exhaust fans, drinking fountains, ice machines, sterilizers, and toilets, to name some of the more dominant noise sources. They have already been discussed in chapter 5, but a few warrant further discussion.

Elevators

Elevators must be located in the area where the traffic patterns require them. A flexible arrangement, however, may be worked out. Where possible, elevators should be in the center of the core; the doors should not face patient rooms. In addition, elevators should be selected for their quietness of operation and the proposed units should be inspected. Many claims for quiet operation of equipment are based on subjective judgment, guess, and pride on the part of the manufacturer. Too many of the elevators in the hospitals studied were noisy in operation and had noisy door-operating mechanisms. As a result, patients in four of the hospitals were exposed to a series of thumps, clicks, and hums every time the elevator stopped at their floor, and in some cases, when the elevator stopped at the floor above or below.

Drinking Fountains

Drinking fountains with self-contained compressors may be completely eliminated by installing a central chilled water system.

Sterilizing Equipment

Sterilizing equipment is installed in many locations, and includes everything from small bedpan sanitizers in subutility rooms to several autoclaves and subsidiary units in a central sterilizing facility. Two types of noise are caused: that of the item to be sterilized as it is loaded and unloaded, and the noise of the operation of the sterilizing equipment.

At Hospital V, for instance, one sterilizing room was located on a nursing-unit floor, as shown on the plan (fig. 1). The equipment room for this sterilizing facility contained a number of pumps and blowers. Much of the sterilizing work was done between 8:00 p.m. and midnight. A considerable amount of noise from the equipment room penetrated all patient rooms on the floor. This noise was transmitted in part by "leakage" through the louvered door of the equipment room. However, the noise leakage alone was not the entire problem. The equipment also transmitted sound through the structure, permitting it to be radiated by the walls and ceilings to adjacent areas. The noise from the loading and unloading of instruments and equipment can readily be reduced by closing the doors to the sterilizing room. This solution, however, leads to ventilation problems. To avoid such noise problems, the ideal solution would be to locate the central sterilizing room in a nonpatient area. If this facility must be located on the same floor, in the same wing, it should be sealed off from the patient areas and the equipment carefully isolated from the building structure in a sealed room without louvered doors. Ventilation for this room can be provided by small blowers and lined ducts.

Another byproduct of the sterilizing process noted was the sound of escaping steam. When the bedpan sanitizer was used, the hiss of escaping steam from the sterilizing unit could be heard throughout the floor. It was particularly annoying at 2:00 a.m. and caused numerous patients to reach wakefulness (even though they may not have been awakened either by the crashing sound of the pan being placed in the hopper or by the flushing of the unit). A pressure-control device upsteam of the sterilizer inlet could reduce such noise greatly. Further reduction in the noise could be achieved through better design for a sealed bedpan sanitizer. Recent models of bedpan sanitizers, however, do operate more quietly than the older ones. Nonpressure types, if properly installed and maintained, produce relatively little noise. A current trend in some hospitals is toward eliminating individual bedpan sanitizers and relegating this function to the central sterilizing facility.

LOADING PLATFORMS

The loading platform was a serious source of noises in all the hospitals surveyed. An exterior, uncovered loading platform permits the noises caused during the unloading and handling of supplies to spread throughout the hospital. The plans of Hospitals M, N, P, and V show loading platforms between the wings that contain the nursing units. This arrangement exposes more patients to noises from the loading platform than any other plan except that of a closed court.

Measurements and observations at several hospitals showed that the sounds made during the delivery of milk and bread early in the morning awakened patients and obviously interfered with their rest. How this noise affected those who did not awaken was determined by direct observation of several patients following the recording of the noise. The effects ranged from mimimal to violent turning and thrashing. These noises and their consequent undesirable effects could be eliminated through suitable planning, as mentioned in chapter 6, by enclosing the loading dock area, by acoustically treating the enclosed area, and finally by administrative changes of supply delivery schedules.

Most existing loading platforms can be modified to provide a considerable reduction in noise. These docks may be equipped with a low roof having a height to accommodate the largest trucks overhanging the outer edge of the loading platform. By pitching the front edge of the roof and by treating the underside with a metal-pan or rigid-block acoustical material, considerable noise reduction can be achieved for all areas of the hospital. In planning for noise control in new construction, interior loading docks might be considered.

PARKING AREAS

At most hospital sites, it is difficult to provide adequate staff and visitor parking areas. Moreover, current planning for parking areas falls short of providing adequate noise control, and the problem is often intensified by the desire to provide separate areas for staff and visitors.

Five examples illustrate this problem: Hospital H provided two parking areas for the staff and the visitors. The one to the north of the building was the source of little noise and was used mainly during the day by outpatients. The lot to the east of the hospital exposed the patients in the east wing to noise, particularly at night, from arriving and departing nurses and physicians. Interchanging the assigned usage of the two parking lots would have eliminated this noise problem.

At Hospital M, the visitors' parking lot was located some distance to the southeast of the hospital and off the end of the wing. The staff parking lot was northwest of the building, off the center of the open court formed by the wings. The noise caused during shift changes was clearly audible in all rooms on the court. Again, reversing the assigned usage of the parking lots would have greatly reduced this problem.

Although reassignment of some of the parking areas might place them farther away from the building than originally planned, such areas could be connected to the hospital by several means, for example, covered walks.

Chapter 9

MATERIALS

The kinds of material used in hospital construction and their influence on noise propagation and its suppression must be carefully considered. Too many people—laymen, engineers, architects—believe that use of "acoustical materials" or "vibration isolators" will completely eliminate any noise problem in hospital areas. A few believe that neither type of product is at all practical. Perhaps an explanation of the functions and purposes of these products will clarify the uses of various materials.

Acoustical materials have been designed to provide a surface of high sound absorption. Vibration isolators, when correctly used, will isolate *most* of the mechanical vibrations from pumps, motors, and compressors from the building. To be fully effective, either material must be used skillfully. One major misconception is the belief that because a material has the word "acoustical" as part of its description, it will isolate sounds from adjacent rooms. Pasting acoustical tile on a lightweight door will not improve the sound isolation provided by the door.

ACOUSTICAL MATERIALS

The fundamentals of an effective noise control program are:

1. Acoustical-absorbing material in the source room or area;
2. A sound-retarding wall with no opening in it;
3. Acoustical-absorbing material in the patient rooms;
4. Minimal flanking sound paths.

The omission of acoustical materials in either the source area or in the patient rooms will raise noise levels considerably. In none of the hospitals studied were acoustical materials used in the patient rooms or in the utility rooms.

The use of acoustical materials throughout all nursing areas would considerably reduce noise levels in all patient rooms from all sources. This will improve rest conditions, reduce annoyance from radios and talk in other rooms, and reduce noise from mechanical equipment heard in patient rooms.

Many types of acoustical materials are readily cleaned with a vacuum cleaner and are available in various impervious substances that do not harbor microorganisms.

In the selection of acoustical materials, the factor of safety to life from fire should not be overlooked. Acoustical materials and systems are available that are incombustible, and, when subjected to fire, will not produce inordinate amounts of noxious smoke or toxic gases.

All materials have some acoustically absorbing properties. For use in a hospital, an acoustical material should absorb at least as much sound as a ¾-inch-thick acoustical tile. For instance, some metal-pan units with ½-inch-thick blanket above the metal pan have relatively poor sound-absorbing quality—but will, of course, cost less than a 1-inch or 2-inch blanket and metal-pan units. Admittedly, there is a monetary saving in using a thin blanket, but for as little as a 10 percent increase in cost for the thicker material, 50 to 100 percent more sound absorption can be provided.

Current practice in handling cemented acoustical tile requires that a finished concrete or plaster ceiling or a gypsum board be used as the base to which the tile is cemented. In multistory hospitals where little noise is generated in patient rooms, acoustical tile may be applied directly to the underside of the slab.

It is imperative that acoustical material be used in corridors. Modern acoustical-ceiling units of glass fiber, in large sizes, can be hung in an economical suspension system below the slab, leaving room for piping and ducts. In utility rooms and floor kitchens, metal-pan or washable surface tile must be used.

WALLS

The problem of sound isolation between patient rooms in hospitals is not as critical as in offices, classrooms, or apartments.

There are no intense noises generated in patient rooms that would require a wall of high sound resistance. Generally, most patient room doors are left partly open at night to permit the staff to observe patients. In fact, the noise is transmitted from room to room more readily through the open doors than through the walls. This does not indicate the use of lightweight or inferior materials for partitions, however. It does mean that a 3-inch or 4-inch block wall, plastered on both sides or painted on both sides with a sealing type of paint, will be adequate between rooms. Metal studs with lath and plaster will also be adequate. Care must be taken to see that no unsealed holes in the wall for heating or plumbing equipment are permitted.

Walls between patient rooms and service spaces, such as utility rooms, kitchens, or toilets, must be of sound-isolating construction. The preferable type is a cavity wall with a minimum of 2 inches of airspace and no unsealed holes. If metal studs with lath and plaster are used for cavity walls, the airspace should be 6 to 10 inches.

For the construction of metal lath and plaster studs between hospital patient rooms, more effective acoustical isolation will be obtained by using ⅜-inch perforated gypsum lath with a minimum of ½-inch sanded gypsum plaster than by applying ¾-inch or ⅞-inch sanded gypsum plaster to metal lath supported by the steel studs. Studs for such walls must be 3¼ inches wide or wider. Walls with panels supported by separate studs placed side-by-side will have even more sound isolation than when the gypsum lath is fastened to opposite sides of the same stud. Such special construction, however, is not required for walls between hospital patient rooms.

It is particularly important to seal walls. All holes for plumbing and electrical equipment should be caulked. Convectors or hot-water piping must not run from room to room in slots or notches in the wall, nor be hidden by convector covers. These are obvious breaches of the wall. Electrical outlets or fixtures placed back-to-back on a wall between two rooms often create passageways for sound, even though the outlets or fixtures are hidden by cover plates.

Not so obvious, however, are the interconnected pores in concrete blocks. A block wall with an imperfectly painted surface may transmit 10 times more sound than a carefully painted wall. The paint must bridge all pores, leaving a closed surface.

Walls should also be sealed at mullions. The increasing use of curtain-wall construction has brought about a special problem. Many of the structural and architectural connections used to join interior walls to exterior walls at their intersections permit sound to leak between the two rooms on opposite sides of the interior wall. Sometimes filler panels are inserted between the edge of the interior wall and the mullion. This construction is particularly vulnerable to sound, and in some cases a gap of ¼ inch can permit conversations in one room to be clearly audible in the adjacent room. A similar problem arises when movable metal walls are used to subdivide a space. In these walls, it is the gap between the runner channels and the floor or ceiling and the gap between the end frames and the building walls or columns that permit the sound to leak past the wall. This may be corrected by using a thin gasket strip of inert flexible material, such as neoprene or vinyl plastic.

CEILINGS

Ceilings should be sealed, too, but in a different way. A common procedure is to hang acoustical ceilings in a space before constructing the walls, and then subdivide the space by erecting walls to the height of the acoustical ceiling. This technique, however, permits noise to pass from one room through the acoustical ceiling into the furred space and down into an adjacent room. Manufacturers have developed special acoustical materials that reduce the amount of sound transmitted from room to room by this construction; but the practice of hanging acoustical ceilings before constructing walls is not recommended for hospitals (although it may provide some economy for other types of buildings). All walls between hospital rooms should extend from the floor to the slab above.

FLOORS

Most floors do not have to be sealed on the surface, but they do require a seal at all penetrations. In the administrator's office at Hospital H, one could hear the noises from the pediatrics playroom. In this section of the building, a vertical heating system pipe from the office passed through an oversized hole in the ceiling and floor to the playroom above. The hole was visually concealed by a decorative escutcheon which did little to block the passage of sound. Sealing such openings will generally prevent transmission of noise between floors, except where the noise sources are mechanical equipment or high-heeled shoes. Mechanical equipment rooms require special consideration of floor and ceiling construction, as outlined in chapter 10.

The problem of noise on the floor below as well as on the same floor from ladies' high-heeled shoes and from the ripple-sole shoes often worn by the hospital staff is not readily solved. It was noted that the noise from the high-heeled shoes was higher in level at those hospitals using hard-tile floors. The noise from the ripple-sole shoes is a squeaking sound and is more predominant after the floors have been waxed.

Floor polishers and waxers, with their high-speed rotary motors, also are sources of high acoustical, annoying noise levels. On the other hand, the relatively quieter process of scrubbing and mopping the floor with a chemical solution involves the use of buckets and mop wringers, which are also noisy. To improve both aspects, current practice indicates the use of a wet pickup vacuum cleaner operated from a central vacuum system. Thus, by not waxing the floors, it is possible to reduce the noise from the rubber-soled shoes as well as eliminate the other sources of annoying noises.

In the selection of flooring materials, the major acoustical feature that appears to be important, according to other studies, is that of resiliency. Other factors, of course, such as cost, appearance, durability, and safety also govern the selection of a floor material. However, a resilient material is not only a quieter material, but is considered to be safer because it permits a greater area of contact with shoes, canes, and crutches, which could otherwise slip. Such slippage is another reason for not waxing floors. Resilience of floor materials will not, however, eliminate all the noise made by walking or by equipment being moved along the floor. No amount of resilience of floor material will prevent poorly maintained wheels on carts from rattling, nor will it reduce noise made by an oxygen tank being dragged across a floor, nor will it influence the transmission of sound along the corridors. All flooring materials possess very little sound absorption, and changing from one to another for this purpose is not warranted. However, other factors are involved in the selection of flooring materials for hospitals, which are outlined in the article, "Characteristics of Resilient Flooring Materials Commonly Used in Hospitals."*

DOORS

As stated in the section on walls, the doors to patient rooms are often left partially or fully open to permit observation of the patients by the nursing staff. Therefore, sound isolation or soundproofing should not be a major consideration in the selection of doors for hospital patient rooms. As found in the study of acoustical levels in Hospitals H and B, shutting the door of a patient's room reduced the high-frequency noise to a level that would be satisfactory, provided the major mechanical noise sources are quieted. Conversation and the noises made when charts are handled at the nurses' stations and the sounds from radio and television sets in nearby rooms will not be transmitted at excessive levels when the doors of rooms are closed.

The doors at these hospitals had bumpers on the bucks which maintained a spacing of about 1/8 inch from the buck at the top and both sides. At the thresholds, there were spaces about 3/4 to 1 inch. These are obviously imperfect seals. However, better door seals may not be necessary in view of the hospitals' practice of leaving doors open.

The problem of noise reduction of doors and door seals is different in the hospital staff's work areas. Doors to kitchens, utility rooms, subutility rooms, mechanical equipment rooms, and pantries must have adequate noise-reducing properties and must have a seal considerably better than that permitted by bumpers on the door bucks. Doors for these spaces should also have a hollow rubber gasket built into the buck or cemented and screwed to it and should have a minimum floor clearance. Rubber or neoprene self-actuating threshold seals at the floor would be desirable, but may present something of a sanitation problem such as accumulations of scrub water around sealing strips. The architect and his engineers, with the guidance of the hospital's administrator and chief nurse, should carefully analyze the requirements of these rooms to obtain the best compromise to the problem in this area.

The doors to most workrooms, except the mechanical equipment room, can be standard 1¾-inch solid-core flush doors. The door to the mechanical equipment room may be lighter if it opens into a nonnursing area, and should be heavier if it opens into a nursing unit. Louvered doors are inadvisable in a hospital, as sounds from noisy rooms can be easily heard in other areas. Doors to storage spaces such as linen closets might be exceptions. However, installing louvered doors to any area may later cause problems, if at some future date rearrangements are made and such spaces are used for other purposes. The cost of installing a short section of lined ventilation duct to workrooms will more than pay for itself by preventing excessive noise transmission.

Auxiliary equipment for doors can also be a source of noise. At Hospitals B and R, numerous door slams were recorded during the noise level study. One of the doorchecks at Hospital N was misaligned with the frame and had developed a vibratory squeak that disturbed patients and staff. Lubricating the doorcheck did not

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*Poiesz, Clemens J., *The Construction Specifier*, 5(2): 8-16, October 1953.

lessen the noise. This condition could have been prevented by careful installation. However, many standard-type doorchecks seemed to be difficult to adjust, with the result that the doors clanged as they were closed. In other instances, doors to linen closets and floor kitchens had neither checks nor cushions on the stops, which resulted in frequent door slamming. Door hinges also are a source of noisy squeaks. It appears that too tight a tolerance on hinge components plus too great a misalignment in installation of the hinges on the doors and bucks are responsible for this source of noise. The remedy is probably the need for greater care in installation and, if possible, a hinge design that requires precision in installation. Essential, frequently used doors should be equipped with ball-bearing, nylon-bearing, or oil-impregnated hinges.

SPECIFICATIONS AND SUPERVISION

Even the best architectural design and the finest materials cannot yield a hospital free from noise if ineffective substitutes are used for the materials selected and if the contractor does not carry out the design with good workmanship. The purpose of a good set of specifications is to prevent substitutions of inferior products, while allowing freedom in the selection of suitable materials. In addition, the specifications can be used effectively to spell out the quality of workmanship required and can serve as a guide for the supervising architect. The supervising architect must assure that the contractors carry out the work as designed. He must also cope with a wide variety of on-the-job problems which, if incorrectly solved, may leave acoustical and architectural flaws in the building. Good specifications and close supervision by an architect who understands the acoustical problems can prevent many of the acoustical faults that would otherwise occur during the construction phase of a hospital or other complex building.

Specifications should stipulate the minimum noise-reduction coefficient of an acoustical material, as well as a minimum thickness for acoustical tiles and a minimum blanket thickness for use with acoustical metal ceilings.

The basic minimal requirements that should be specified are as follows:

For acoustical tile in patient rooms, the minimum thickness must be ¾ inch and the minimum noise-reduction coefficient (NRC) must be 0.65. Where plastic-faced mineral-fiber tile is used, however, a minimum noise-reduction coefficient of 0.60 may be accepted. Where metal-pan acoustical ceilings are used with a pad, the pad must be mineral wool, paper-wrapped to a minimum thickness of 1¼ inches, and must be spaced from the metal pan by means of a wire grid. Flame-proofed paper must be specified for wrapping these pads. Blankets for use with metal-pan ceilings must be a minimum thickness of 1 inch, must not contact the inside face of the metal pan, and must be laid continuously end-to-end and side-by-side so that all the metal pan is covered by the blanket. The minimum noise-reduction coefficient for such ceilings should be 0.60. The metal pans discussed here are those that have closely spaced perforations, not the decorative slotted pans. The decorative slotted pans cannot provide the high sound-absorption coefficients required for hospital use. Although the foregoing discussion is based on the minimum requirements, it should be pointed out that a 2-inch-thick blanket material is considerably more effective than a 1-inch blanket; the minimum density to be specified must be three-fourths pound per cubic foot. If a sterile atmosphere must be maintained, a 0.001-inch or 0.0015-inch-thick plastic bag, wrapper, or facing may be specified with the blankets.

Restrictions as to the exact number of holes per square foot, the exact thickness (not the minimum), and the surface finish should be indicated to whatever degree preferred by aesthetics, but these features should not be the controlling factors in specifying acoustical materials for hospitals. Other basic specifications for acoustical materials should include the primary material and the suspension system by which the required sound absorption is to be achieved, since most acoustical materials behave differently in different suspensions. The required sound-absorption coefficients of the primary material are based on having the acoustical tile cemented to a concrete or plaster ceiling. The acoustical metal-pan ceiling noise-reduction coefficients are based on having an air-space of approximately 10 inches above the metal-pan face. Excellent results with the acoustical tile may be obtained by nailing it to nominal 1-inch by 3-inch wood furring, either 12 inches or 24 inches on center as required. Satisfactory results may also be obtained from the metal-pan systems if they, too, are attached to 1-inch by 3-inch wood furring. However, if such deviations from the basic recommendations above are contemplated, the architect or the acoustical consultant should examine the sound-absorption coefficients of the material and the intended method of installation to assure that performance will correspond with requirements.

The method of installation, closure, and sealing of "soundproofed" doors should also be specified.

Paint for sealing block walls should be fully detailed in the specifications. The method of sealing joints at mullions and the joining of inside partitions should be thoroughly described. Details should not be left to the contractor under the phrase "all work shall be performed in a neat, workmanlike manner." Specifications for plumbing and electrical work should include exact descriptions of the penetrations in walls and ceilings and the method of closure required to prevent transmission of sound through the openings provided for the pipes and conduit.

For machinery, the specifications should include the type of vibration isolation to be provided for the equipment and the maximum permissible sound-power output for any given machine. Certification by the manufacturer that the equipment noise output under test conditions does not exceed the specified values should be submitted by the contractor. Standard acoustical engineering procedures for calculating the sound level in the equipment spaces and in patient rooms, as well as in the corridors and staff areas, may be applied to determine the maximum permissible sound-power output to be specified. Techniques for measuring sound levels and for quieting equipment have been improved in the past few years, and are readily available. There is no longer any reason for omitting noise-output limitations from the architectural and engineering specifications for hospitals.

Supervision of the construction must include the examination of cavity walls to be sure that rubble does not bridge two walls that should be completely independent. The installation and "soundproofing" of doors, the installation and loading of vibration isolators, and the installation of vibration-isolating pipe hangers also must be carefully supervised. Inspection must be made to assure that pipe and conduit pentrations have been sealed as specified, and that penetrations have not been made merely for the convenience of effecting a short cut for the installation of a duct or a conduit.

Installation of flexible pipe sections and flexible couplings requires careful attention. Incorrect positioning of flexible piping and too great a misalignment of shafts on opposite sides of flexible couplings will limit their usefulness as noise suppressors.

The supervising architect must also be alert to the importance of accurate installation of complex sheetmetal ductwork and the possible means by which a well-designed ventilating or air-conditioning system can become a series of speaking tubes transmitting speech and mechanical noise throughout the building as airborne sound.

Finally, the supervising architect must identify and correct acoustical details that may have been overlooked during the design phase, such as fans that may have been mounted on patient room walls in the furred space above the ceiling, but should have been suspended from the roof; wall intersections that may form sound leaks because of the differences in materials or the unevenness of a seal between a sheetmetal channel and a masonry wall; insufficient ventilation for a utility room with steam sterilizing equipment (these rooms are often ventilated similar to toilet rooms, but require larger air volumes because of the steam); and the other details of the construction that may have violated the intent of the design.

Most materials now available, when used effectively in conjunction with appropriate plans, suitable building location, and good design, can overcome many of the complex noise problems in hospitals. On the other hand, the specifications and supervision of the construction must also be coordinated with the design of the structure and selection of the materials to attain a quiet hospital.

Chapter 10

DESIGN GOALS FOR NOISE CONTROL

MAXIMUM SOUND LEVELS

In chapter 4 and figure 135 in appendix B, the NC–30 (noise criteria) curve was used as a design objective goal for patient rooms in hospitals. The curve shows the noise levels for an unoccupied patient room and other general activities (those shown in each chart) within a normal range. Data in this form are of little use for writing specifications for equipment noise. It is possible, however, to categorize the sources by type and to specify noise limits for various pieces of equipment. Dishwashers, pumps, air conditioners, exhausters, sterilizers, and refrigerators, to name a few items, can have their noise levels specified in such a way that a manufacturer can design the equipment to meet the specification. In this way, noise from these sources can be minimized.

Tables 8 and 9 give the recommended maximum allowable noise levels for various items of equipment. Two types of rating are given. The first, in table 8 (A and B), which gives the sound-pressure level measured 6 feet from the equipment, is now used, but is being revised and should be replaced as soon as a standard method for measurement of sound-power level is adopted by the American Standards Association. After that, table 9, which gives the sound-power level of the device, should be used. (In any case, the consultants recommend that a change to sound-power level be made no later than January 1, 1965. By that time, most major equipment manufacturers should have facilities for making these measurements in order to meet industrial rating codes.)

The method of reading the sound-pressure level also is specified in table 8 (A and B). The schedule numbers referred to in the tables are listed in the sound rating schedule of hospital noise sources (page 66).

Table 8.—Recommended maximum avarage sound-pressure levels*

A. For machines with maximum dimension of less than 6 feet

Sound-pressure levels are to be measured at 6 feet from each machine in at least five positions on each side and above and below (if machine does not sit on floor). Readings shall be averaged arithmetically, except that all readings more than 10.0 decibels below the maximum reading shall be disregarded in taking the average.

Frequency band, cps	Sound-pressure level re 0.0002 microbar							
	20–75	75–150	150–300	300–600	600–1200	1200–2400	2400–4800	4800–9600
Schedule I	60	51	43	37	32	30	28	27
Schedule II	63	55	47	41	37	35	33	32
Schedule III	75	68	64	64	64	64	64	64
Schedule IV	100	95	91	87	84	82	82	82

Footnote at end of table.

Table 8.—Recommended maximum average sound-pressure levels—Continued .

B. For machines with dimension of 6 feet or more

Sound-pressure levels are to be measured at 6 feet from each machine in at least five positions on each side and above and below (if machine does not sit on floor). Readings shall be averaged arithmetically, except that all readings more than 10.0 decibels below the maximum reading shall be disregarded in taking the average.

Frequency band, cps	Sound-pressure level re 0.0002 microbar							
	20–75	75–150	150–300	300–600	600–1200	1200–2400	2400–4800	4800–9600
Schedule I	55	47	40	32	27	25	25	25
Schedule II	58	50	42	36	32	30	30	30
Schedule III	71	63	60	60	60	60	60	60
Schedule IV	95	90	86	82	89	77	77	77

*If hospital rooms do not have acoustical treatment of ¾-inch tile or equivalent on ceiling, subtract 8 decibels from all maximum sound levels.

Table 9.—Recommended maximum sound-power levels*

Frequency band, cps	Sound-power level in decibels re 10^{-12} watt							
	20–75	75–150	150–300	300–600	600–1200	1200–2400	2400–4800	4800–9600
Schedule I	57	51	45	43	38	36	34	33
Schedule II	62	66	51	50	46	45	44	43
Schedule III	72	68	66	70	70	70	70	70
Schedule IV	100	98	95	94	92	90	89	88

*If hospital rooms do not have acoustical treatment of ¾-inch tile or equivalent on ceiling, subtract 8 decibels from all maximum sound levels.

SOUND RATING SCHEDULE FOR PREDOMINANT HOSPITAL NOISE SOURCES

Noise Source (equipment)	*Schedule*
Air conditioning, 6 feet from duct opening, patient room	I
Air conditioning, 6 feet from duct opening, corridor	II
Boiler room equipment	IV
Dishwasher	III
Elevator, corridor 6 feet	II
Elevator door mechanism	II
Elevator machinery, mechanical equipment room	IV
Flush valves, corridor toilet	III
Flush valves, private toilet	I
Ice machine, corridor	II
Ice machine, pantry or kitchen	III

Noise Source (equipment)	*Schedule*
Mechanical ventilation equipment (in separate room) (noise through casing; air ducted out of test room)	IV
Refrigerator, nurses' station	II
Refrigerator, pantry or kitchen	III
Roof ventilators, direct, 1 foot from intake	II
Roof ventilators, ducted to toilets, other areas	II
Room air conditioner	II
Room fans	I
Sterilizers (steam cycle)	III
Transformers, in vault or equipment room	II
Transformers, out of doors, within 50 feet of building	II
Water cooler, corridor	II

VIBRATION ISOLATION

Since vibration is transmitted by many paths and is converted to acoustical energy by a variety of means, it is not possible to calculate accurately the noise levels that will be produced by any given piece of equipment, even if all its vibration characteristics are known. The nature of vibration isolation, however, makes it possible to obtain sufficient vibration isolation with little more effort or expense than is required to obtain marginal isolation. Thus, for specifying noise level requirements, the parallel may be made that no device or group of devices operating as a unit shall produce mechanical vibrations that cause the noise level in any patient room (unoccupied) to be above the NC–35 level and that a certain minimum amount of vibration isolation shall be provided. Noise from mechanical vibrations that exceed these levels shall be considered evidence of noncompliance with the vibration-elimination clause of the contract. (*Note:* The noise level criteria should be stated in the specification. The NCA curves should not be used, since these curve criteria permit higher low-frequency levels than the same NC curve value. The NCA values may be satisfactory for offices, but they are not suitable for hospital patient rooms and nurses' stations.)

As previously mentioned, the elimination or control of mechanical vibration in mechanical equipment usually is covered in the specifications by a catchall paragraph too general to achieve its purpose. The following paragraphs on vibration isolation, modified to conform to the requirements, are suitable for this purpose and should achieve the recommended limits.

Vibration isolation.—All floor-mounted mechanical equipment, unless specified to the contrary, shall be supported by 4-inch-high, suitably reinforced, concrete pads under the complete floor area of each machine or piece of equipment.

All major items of equipment, such as fans, compressors, and pumps shall be mounted on inertial blocks of concrete. The weight of the block shall be equal to twice the weight of the machine including motor, pulleys, and so forth, or shall have a minimum thickness of 4 inches, whichever provides the greatest weight. The inertial block shall be reinforced to support the dynamic loads carried, but in no case shall the reinforcement be lighter than ¼-inch welded steelwire mesh (spaced 4 inches) *top* and *bottom* with ends turned up from bottom and down from top. A minimum of ¾-inch concrete shall cover the steel reinforcing.

The inertial block shall be supported in one of two ways:

1. By spring-type isolators with at least 1-inch deflection and with a ribbed rubber or neoprene pad loaded to produce a deflection of $1/16$ of an inch under the base of the spring. The pad shall be $5/16$-inch to ⅜-inch thick initially and shall deflect approximately $1/16$ of an inch under a 50-pound-per-square-inch load.
2. By rubber-in-shear rail isolators with a loaded deflection of $1/16$ of an inch.

Flexible hose, pipe, conduit, and canvas sleeving shall be installed between all air, gas, fluid, or electrical lines and all equipment.

AIR CONDITIONING

The noise made by air-conditioning equipment can be controlled quite readily. The design objective noise levels can be specified for the two critical areas, patient spaces and nurses' stations, as well as for surgery suites, delivery rooms, and offices. The mechanical engineer can then select fans, mixing boxes, diffusers, grilles, and sound traps to meet the design objective.

Many roof ventilators used (such as those at Hospitals B and R) are marginal, but the use of acoustical material in the rooms would reduce the interior sound levels to below the design objective. Recommended design objective sound levels for various hospital spaces are presented in table 10.

CARTS

Numerous problems arise when attempts are made to set acceptance specifications, based on noise level, for carts. The major problem is that new carts are not noisy and present no immediate problem, but after the carts have been in use for a few months they may become as noisy as those in use for over a year.

Specifications for carts should stipulate that the carts must have elastic stop nets on wheelposts and sanitary, heavy damping on the undersides of the shelves.

One criterion for carts is that the panels should be damped by a deadener capable of producing 2 percent of critical damping, which is equivalent to a decay rate of 150 decibels per second by the Geiger method of rating.* The pertinent phase of this method is summarized as follows:

> The Geiger method of rating panel deadeners is based on a standard test of the deadener when applied to a 20- by 20-inch cold-rolled steel panel ¼-inch thick and weighing about 30 pounds. When

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*Hamme, Richard N., "Materials and Techniques for Damping," *Noise Control, Vol. 3, No. 2,* March 1957, pp. 23–26.

Table 10.—Recommended design objective sound levels

	Octave band sound-pressure levels							
Frequency band, cps	20–75	75–150	150–300	300–600	600–1200	1200–2400	2400–4800	4800–9600
Patient room (NC–30)	60	51	43	37	32	30	28	27
Nurses' station (NC–35)	63	55	47	41	37	35	33	32
Surgery and delivery (NC–40)	66	59	52	46	42	40	38	37
Offices:								
Private (NC–35)	63	55	47	41	37	35	33	32
General (NC–45)	69	62	56	50	47	43	43	42

the panel is suspended to vibrate freely, it will resonate at 160 cycles per second (cps). The panel is caused to vibrate by a magnetic exciting unit which excites the panel at its 160-cps resonant frequency. Automatic equipment shuts off the exciting signal and measures the rate at which the vibrations of the panel die away. It has been determined for the ¼-inch steel plate that at a decay rate of 150 decibels per second (db/sec) at its resonant frequency of 160 cps, the point of diminishing returns sets in for the use of panel deadeners. (The 150-db/sec rate corresponds to a damping which is 2 percent of critical damping.)

To determine the particular damping required for panels thinner than ¼ inch, it is only necesary to determine the required decay rate for the different panel. This may be done by taking the ratio between ¼ inch and the thickness of the panel in question and dividing 150 by this ratio. The quotient is then multiplied by the ratio of 160 cps to the resonant frequency of the panel in question.

In the example below, a particular 16-gauge sheet steel panel, which is about one-fortieth as thick as the ¼-inch test panel, had an 80-cps resonant frequency, or one-half the 160-cps resonant frequency of the ¼-inch panel. Carrying out the application stated above, we find that we need deadening material which has a vibration decay rate of approximately 8 db/sec.

Example: $\frac{0.250}{0.061} \times \frac{160}{80} = 8$ db/sec (approx.)

Another noise control measure for carts is to check the wheel-bearing assembly. Wheel-bearing assemblies that permit separation of the ball-bearing grooves when the cart is lifted from the floor will generate noise as the cart moves across uneven floors. To avoid this occurrence, tighter tolerances on the bearings, or self-locking nuts on adjustable bearing assemblies, or nuts and cotter-key locks should be specified. The tolerances or prescribed limits have not as yet been determined for wheel-bearing assemblies of carts, but a series of tests on adjustable bearing units mounted on a cart would provide an interim specification.

BEDSIDE SUCTION AND PUMP EQUIPMENT

Suction and pump equipment, like the dishwashers and refrigerators, also can have their sound-power levels specified. To minimize annoyance to patients in adjacent and nearby rooms, the sound levels in table 11 should be specified as maximum to be acceptable.

Table 11.—Maximum allowable sound levels of bedside equipment operating in patient room

	Octave band sound-pressure levels							
Frequency band, cps	20–75	75–150	150–300	300–600	600–1200	1200–2400	2400–4800	4800–9600
Octave band power level re 10^{-13} watt	67	61	60	57	54	54	54	53
Maximum allowable sound-pressure level: 1 foot	73	66	60	55	53	53	53	50

SINKS, CABINETS, AND DRAWERS

Sinks, cabinets, and drawers that cause noise when they are struck can be quieted (see page 41) in a manner similar to the cart panels. Appropriate damping materials can reduce the decay rate, which in turn reduces the sound output. Therefore, the same requirement as that used for carts would be applicable: a decay rate less than 150 decibels per second at the resonant frequency of the panel, as tested in accordance with the Geiger method of rating.

FLOORS, WALLS, AND CEILINGS

The study has shown that floors, walls, and ceilings are not critical structures between patient spaces. However, walls between patient rooms and noisy areas, where such an arrangement cannot be avoided, must have high transmission-loss values to isolate the particular noise source from the adjacent patient room sufficiently to provide NC–30 levels or lower in the room.

Floors and ceiling of patient rooms must also be analyzed and specified for sound isolation from the noise sources; they must also be checked for vibration transmission.

The acoustical design goals for hospitals as briefly outlined above are planned to provide an NC–30 noise level curve in the patient areas. This curve, used as the criterion for measuring sound levels (unaccompanied by the noise of bedpans, bedpan sterilizers, or radios), should effect adequate quiet conditions in patient rooms.

Part IV

CHECKLIST OF RECOMMENDATIONS

Chapter 11

CHECKLIST: SUMMARY OF RECOMMENDATIONS

The body of this report contains a number of recommendations and suggestions for the elimination or reduction of hospital noises. The summary of recommendations presented here may be used as a checklist to ensure that items are not overlooked in the design. This summary, however, should not be used as design guide material without referring to the original discussions. As the report is devoted to acoustical considerations exclusively, the importance of each recommendation must be weighed against other factors in each case.

Those responsible for the final designs—architects, engineers, administrators, and manufacturers—should have an understanding of the reasons behind the acoustical recommendations, so that suitable judgment may be applied to any compromise decisions.

INTERIOR NOISE SOURCES

Mechanical Equipment

1. Furnaces and combustion units should be selected with consideration for their noise output.
2. Pumps should be selected in accordance with sound ratings.
3. Flexible pipe links, flexible electrical conduit, and vibration isolators should be used to minimize noise transmission to the rest of the building.
4. Intake and exhaust fans should be selected on the basis of sound output and should be mounted on vibration isolators and connected to ductwork by canvas sleeves.
5. Pulsation absorbers or snubbers should be used where several pumps are connected to a common header.
6. Piping to vibration-generating equipment must be supported by vibration-isolated hangers.
7. Water hammer can be eliminated by lowering operating pressures and/or in combination with a small snubber.
8. Transformers located in a vault should be mounted on a vibration-isolating material.
9. A cavity wall or suspended ceiling should be placed on the room side of the vault, if the transformer vault is located adjacent to or below a patient room.
10. Ventilation louvers for transformer vaults should not open beneath patient room windows.
11. Transformers located out of doors should be selected for quietness.
12. For out-of-door transformer installations, additional noise reduction may be obtained by the erection of a sound-barrier wall.
13. If the mechanical air-conditioning room is adjacent to nursing areas, switchgear should be fully enclosed in surface-mounted or free-standing cases supported on vibration isolators.
14. In the ductwork, breaks consisting of short sections of canvas sleeving will block the transmission of mechanical vibration.
15. Duct lining, lined turns, lined plenums, or prefabricated sound traps should be used, where feasible, to minimize passage of sound along the ductwork.
16. The return air system, as well as the supply air ducts, must be treated.
17. Fans should be selected, installed, and operated for minimum noise output.
18. Compressors with flexible link connections and adequate intake silencers should be mounted on vibration isolators in a suitably isolated space.
19. The air-conditioning equipment room should be acoustically treated.

20. Roof ventilators should be selected and installed for minimum noise output.

Operational Facilities

21. Elevators and doors should operate with maximum quietness. (For remedial suggestions see pages 38 and 61.)
22. Elevators should be placed in central core of building, if possible, with doors not facing patient rooms.
23. Refrigerators should be specified for quiet operation; sealed compressor units are preferred.
24. Refrigerator motors and compressors should be mounted on a common base provided with vibration isolators.
25. The compressor unit, as with reciprocating compressors, may be placed in a double-walled box with sound-isolating ducts, if necessary.
26. Water coolers (drinking fountains) should be selected, located, and installed with regard to quiet operation.
27. Ice machines, if located near patient areas, should be selected for quiet operation and should be fully enclosed. If ventilation is required, a small ducted blower should be used rather than louvered doors.
28. Dishwasher noise may be minimized by regulating steam pressure, sealing cabinets, damping sheet-metal, and by using vibration isolators.
29. Central sterilization rooms should be located away from patient areas; if not, the rooms must be isolated from the building and sealed. Such rooms should have ventilation blowers and lined ducts; louvered doors should not be used.
30. Faucets, particularly at the nurses' stations, should have the water pressure regulated for quiet operation.
31. Metal sinks or basins should be damped with an undercoating material.
32. Silencers should be specified for flush valves for clinical sinks and toilets.
33. Steam pressure sterilizers for bedpans should seal continuously at the lip.
34. Metal sinks and cabinetry should be treated with a damping compound to reduce sound radiation; the use of a laminated construction is suggested.
35. Cabinet doors and drawers, if possible, should be equipped with silent closing devices.
36. Chart cases should have laminated construction, plastic jackets, handles or finger loops, and sloping shelf racks with damped or undercoated shelves, to reduce noise caused when handling the charts.
37. Bed adjustment noises may be reduced by appropriate maintenance, including lubrication.
38. Bedrail sounds may be reduced by the use of replaceable plastic inserts or sleeves.
39. The most practical means of reducing the noise caused while adjusting bed curtains is by slower and more careful handling on the part of hospital personnel.
40. Installation of a central vacuum system for cleaning should be considered.
41. Floor polishers should be selected on the basis of sound output and scheduled for use at hours when they will be least annoying.
42. Housekeeping equipment, such as pails and trash containers, may be quieted by the use of rubber rings and damping materials.
43. Voice-paging equipment can be made less annoying through operational procedures, such as adjusting sound levels.
44. Telephone bell noise can be minimized by using quiet bell tones or another type of signal, such as buzzers, gongs, or lights.
45. Patients' call-bell or buzzer systems should be adjusted to the lowest practical level. The use of a chime and light system should be considered.

Patient Service Facilities

46. Cart noise can be kept to a minimum by careful design selection and proper maintenance.
47. Carts with large wheels generally are less noisy than those with small wheels.
48. Cart shelves may be undercoated with a sound-deadening compound and/or fabricated with a laminated construction to reduce noise.
49. Cart tops shaped with appropriate depressions or equipped with special polyethylene trays would eliminate the noise made by the rattling of glass and metal items.
50. Laminated construction of metalware will reduce noise generated in handling metal articles.
51. A central outside oxygen storage area with piping to each room would eliminate sounds related to the transportation and changing of oxygen tanks.
52. The rattling of instrument cases transported on carts can be reduced by using soft plastic-jacketed cases, neoprene spot-type-deadener bumpers, or by hand-carrying the small cases.
53. Radio and television noise can be reduced by acoustical treatment of patient rooms, by modifying the sets, or by permitting only the use of earphones or pillow loudspeakers.

DESIGN, CONSTRUCTION, AND FUNCTIONAL CONSIDERATIONS

Planning, Site, and Form of Building

54. Patient rooms preferably should not face the street or other exterior noise sources, such as nearby railroads.
55. L- or T-shaped floor plans are preferred.
56. Corridors should be short. A central core area for all facilities is preferred.
57. Doors to opposite rooms should be staggered.
58. Closed courts are not desirable.
59. In choosing a site, the following points should be considered:
    a. Distance from exterior noise sources.
    b. Use of other buildings as sound barriers.
    c. Effects of nearby high buildings as sound reflectors.
    d. Nearby highway grades.
    e. Nearby traffic lights.
    f. Traffic volume.
    g. Mechanical plant in a separate building usually is preferable.

Hospital Nursing Facilities

60. Utility and subutility rooms should be treated with acoustical materials.
61. Utility room equipment should be selected for quiet operation.
62. Doors to utility rooms should be equipped with rubber gasket stops.
63. Passageways connecting utility rooms to nursing unit corridors should be treated with acoustical materials.
64. Ventilating systems for floor kitchens and pantries should be adequate to handle heat and steam generated by equipment; both fresh air and exhaust air should be ducted.
65. Doors to corridors should be solid-core flush doors without louvers equipped with a gasket at the head and jamb.
66. Mechanical equipment should be selected for quiet operation.
67. Connecting pipes and mounting brackets should be isolated from the building structure by means of resilient hangers.
68. Although kitchens and pantries should be located convenient to patient rooms, it is advisable to provide surrounding buffer zones by means of storerooms or closets.
69. Where kitchens or pantries are located adjacent to patient rooms, the use of a double-partition wall is imperative.
70. Nurses' stations should not be too close to patient rooms, should be enclosed, and should be acoustically treated.

Operational Features

71. Steam noise from bedpan sanitizers can be reduced by using pressure-control devices; consideration also should be given to selection of well-designed equipment.
72. Loading platforms should be located away from patient room wings. If an interior loading dock is not feasible, the exterior platform should be provided with an acoustically treated overhanging roof.
73. Location of parking areas should be carefully planned. (Staff parking is most apt to create noise at undesirable hours.)

Materials

74. Use of acoustical absorbing materials in patient rooms and throughout the entire nursing areas would reduce noise levels considerably.
75. Painted 3- or 4-inch block wall, plastered on both sides, is adequate between patient rooms, provided all holes for piping, heating, and electrical outlets are sealed.
76. Cavity walls should be used between patient rooms and adjacent service rooms.
77. Walls should be well sealed by caulking all holes and using a pore-sealing paint.
78. Where suspended acoustical ceilings are used, such as in corridors, all room walls must extend to the slab above.
79. In curtain-wall construction, walls must be sealed at mullions.
80. Movable metal subdividing walls should be sealed at runner channels and end frames; the use of a thin gasket of neoprene or vinyl plastic is recommended.
81. Pipe and conduit penetrations through floors should be sealed.
82. Doors to kitchens, pantries, utility rooms, and mechanical equipment rooms should have adequate noise reducing properties.
83. Louvered doors should not be used.
84. Doorchecks and hinges should be carefully selected and properly installed.
85. Detailed specifications and close supervision are required for construction and equipment installation to ensure adequate noise control.

The recommendations made in this report and outlined in this summary are not always simple to effect nor are they in all cases inexpensive. The objective has been to determine those acoustical conditions conducive to improved patient rest. As in other areas of design, many compromises will be necessary, but each should be made on the basis of achieving a quiet patient area as compared with a noisy one.

The purpose of this survey will have been served if hospital architects, engineers, and administrators are stimulated into carrying out programs leading to the construction of quieter hospitals.

Part V. APPENDIXES

Appendix A. Letter and questionnaire form sent to discharged patients

Appendix B. Graphic measurements of hospital noises

Appendix A

LETTER AND QUESTIONNAIRE FORM SENT TO DISCHARGED PATIENTS

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE • WASHINGTON 25, D. C.

BUREAU OF MEDICAL SERVICES

Refer to:

The U. S. Public Health Service is seeking information which will lead to improved hospital design. It is currently engaged in exploring the problem of noise, particularly those noises which annoy the patients or interfere with their rest.

Mr. Lewis S. Goodfriend and Mr. R. L. Cardinell, acoustical consultants for the U. S. Public Health Service, are making acoustical studies in a number of existing hospitals. They include analyses of typical noises and the determination of patient reaction.

As a recent hospital patient, you possibly have some opinions on the subject. We request your cooperation in filling out and returning the attached questionnaire. Your answers to the questions will be of great value in determining the recommendations to be made concerning future hospital construction. It is not necessary to sign your name. The enclosed return envelope requires no postage.

Please note that sounds which irritate or annoy are not necessarily the loudest ones. Much depends on the general background noise, the time at which they are heard and your own condition or state of mind at the time.

Your help in this matter will be of significant value to our study and will be greatly appreciated.

Sincerely yours,

Jack C Haldeman

Jack C. Haldeman
Assistant Surgeon General
Chief, Division of Hospital and
Medical Facilities

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DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE

BUDGET BUREAU NO. 68-6833
APPROVAL EXPIRES 12-31-68

ACOUSTICAL QUESTIONNAIRE

HOSPITAL NAME				ROOM NO.
NATURE OF ILLNESS				LENGTH OF STAY
PATIENT'S	AGE	SEX ☐ M ☐ F	OCCUPATION	

A The following list covers many of the frequently encountered noise sources in hospitals. In each case please circle the descriptive word or phrase which applied to the ones you can identify, indicating: (1) Whether you did not hear it, (2) Whether you noticed it, (3) Whether it bothered you.

TALKING IN CORRIDORS (VISITORS)	NOT HEARD	NOTICED	BOTHERED
TALKING IN CORRIDORS (STAFF)	NOT HEARD	NOTICED	BOTHERED
TALKING IN OTHER PATIENTS' ROOMS	NOT HEARD	NOTICED	BOTHERED
WALKING IN CORRIDORS	NOT HEARD	NOTICED	BOTHERED
SLAMMING DOORS	NOT HEARD	NOTICED	BOTHERED
PANTRY AND/OR KITCHEN NOISE	NOT HEARD	NOTICED	BOTHERED
FOOD SERVICE: DISH & TRAY CLATTER	NOT HEARD	NOTICED	BOTHERED
CARTS - MEDICINE, LINEN, ETC.	NOT HEARD	NOTICED	BOTHERED
ELEVATORS, ELEVATOR DOORS	NOT HEARD	NOTICED	BOTHERED
VOICE PAGING SYSTEM	NOT HEARD	NOTICED	BOTHERED
CALL BELL SYSTEM	NOT HEARD	NOTICED	BOTHERED
PATIENT'S CALL BUZZERS	NOT HEARD	NOTICED	BOTHERED
TELEPHONES	NOT HEARD	NOTICED	BOTHERED
RADIOS OR TELEVISION SETS	NOT HEARD	NOTICED	BOTHERED
TOILET FLUSHING	NOT HEARD	NOTICED	BOTHERED
BED PAN WASHER	NOT HEARD	NOTICED	BOTHERED
FANS, AIR CONDITIONERS	NOT HEARD	NOTICED	BOTHERED
WATER RUNNING FROM FAUCET	NOT HEARD	NOTICED	BOTHERED
COOLERS, FOUNTAINS, REFRIGERATORS	NOT HEARD	NOTICED	BOTHERED
CLEANING EQUIPMENT, BUCKETS, ETC.	NOT HEARD	NOTICED	BOTHERED
TRASH CONTAINERS	NOT HEARD	NOTICED	BOTHERED
FLOOR POLISHERS	NOT HEARD	NOTICED	BOTHERED
HIGHWAY OR STREET TRAFFIC	NOT HEARD	NOTICED	BOTHERED

(Continue on reverse)

A Continued

AIRPLANES	NOT HEARD	NOTICED	BOTHERED
TRUCKS AT SERVICE ENTRANCE	NOT HEARD	NOTICED	BOTHERED
OTHER SERVICE ENTRANCE NOISES	NOT HEARD	NOTICED	BOTHERED

B Please list or describe any other sounds which you found bothersome or irritating.

C Which of the above noises bothered you most? If more than one, please list the worst offender first, and the others in decreasing order.

D Could you hear noises in adjacent rooms with your door closed?

☐ No ☐ Faintly ☐ Clearly

E Did any noises awaken you from sleep? ☐ No ☐ Yes
If answer is "yes," please describe. Also indicate approximate time of day or night.

F We would be pleased to receive any additional comments you would care to make regarding hospital noise.

Appendix B

GRAPHIC MEASUREMENTS OF HOSPITAL NOISES

In addition to the investigators' observations and the comments tabulated from the patients' questionnaires described in chapter 3, graphic measurements were made of specific and background sounds, based on standard noise measurements and recording techniques, as discussed in chapter 4. The results of these analyses are shown under five sections, grouped as follows:

Section 1. Most annoying noises in patient rooms and corridors (charts 1–10.)

Section 2. Background sound levels: 2:00 to 3:00 a.m. (charts 11, 12.)

Section 3. Continuous 24-hour record of background sound levels, based on hourly samples. (Octave band analyses: overall level, octave band levels, A-weighted level.) (charts 13–20.)

Section 4. Specific sounds and average background levels. (charts 21–134.)

Section 5. Noise criteria for patient room and nurses' station. (chart 135.)

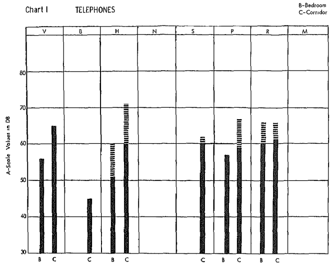
Section 1. *Most annoying noises in patient rooms and corridors.*

This group of charts shows the noises as recorded and confirmed by the patients' questionnaire study. In reviewing these charts, it should be realized that the closer a sound source is to the microphone, the higher the sound level will be. Also, a given type of sound, such as the clatter of dishes or a dropped pan, will not always register the same level.

Where the bars are shown with shaded upper portions. several sounds of that particular category were recorded and identified. The solid portion of the bar extends to the lowest reading and the shaded portion to the highest. Bars without shaded portions indicate that only one sound of that category was recorded and identified, or that several sounds achieved identical values. The absence of a bar indicates that there was no positive identification of the particular sound.

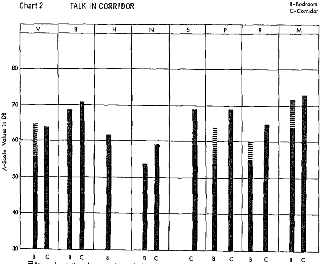
For example, chart 1, Telephones, shows decibel (db) readings of 56 and 65 for a patient room and corridor, respectively, in Hospital V. In Hospital B, no telephone bell was noted in the patient room, while a level of 45 db was recorded at the corridor location. In Hospital H, several telephone bells were recorded in each location, ranging from 51 to 60 db in the bedroom and from 60 to 71 db in the corridor.

Chart I TELEPHONES



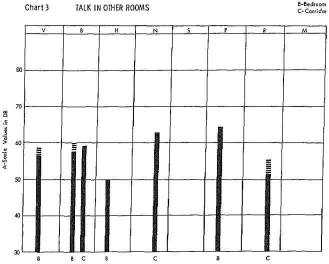
≡ Range of variation when more than a single sound in the category is included.

Chart 2 TALK IN CORRIDOR



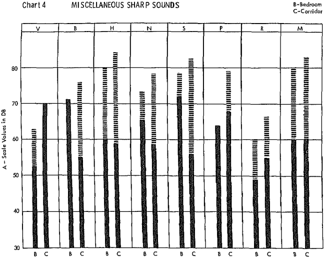
≡ Range of variation when more than a single sound in the category is included.

Chart 3 TALK IN OTHER ROOMS



≣ Range of variation when more than a single sound in the category is included.

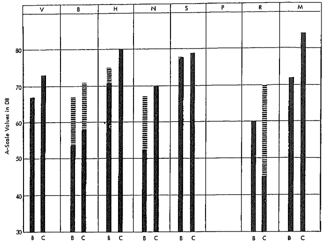
Chart 4 MISCELLANEOUS SHARP SOUNDS



≣ Range of variation when more than a single sound in the category is included.

Chart 5 DISH AND TRAY NOISE

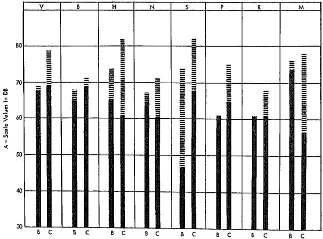
B-Bedroom
C-Corridor



☰ Range of variation when more than a single sound in the category is included.

Chart 6 CARTS

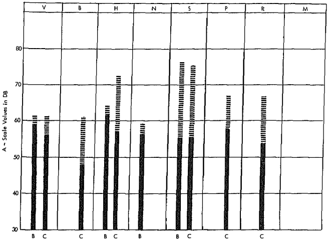
B-Bedroom
C-Corridor



☰ Range of variation when more than a single sound in the category is included.

Chart 7 FLOOR KITCHEN, UTILITY ROOM

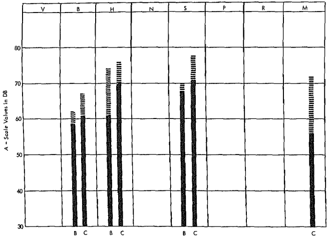
B-Bedroom
C-Corridor



☰ Range of variation when more than a single sound in the category is included

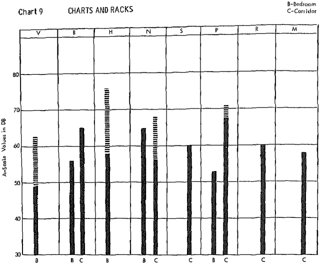
Chart 8 PAGING SYSTEMS

B-Bedroom
C-Corridor



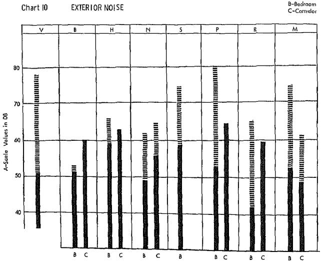
☰ Range of variation when more than a single sound in the category is included

Chart 9 CHARTS AND RACKS



▤ Range of variation when more than a single sound in the category is included.

Chart 10 EXTERIOR NOISE



variation when more than a single sound in the category is included.

Section 2. *Background sound levels: 2:00 to 3:00 a.m.*

These charts, recorded from charts 2, 4, and 6 (see Section 1), show the background sound levels by octave bands in patient rooms and in corridors; the measurements represent about the lowest noise level achieved in the hospitals. The heavy line on the charts marked NC–30 represents the criterion for ideal sleeping conditions in patient rooms. All points of the recorded octave band curves should lie below this criterion.

Note that the curves for the patient room and the corridor, for Hospital P, reflect the fact that two oxygen tanks were in continual operation in a nearby room, with the door open during the entire survey. Also, the curves for Hospital H (rooms 307 and 535, third- and top-floor patient rooms) reflect a considerable difference in background levels, which indicates the noise of the air-conditioning equipment on the roof.

Chart II BACKGROUND SOUND LEVELS--PATIENT ROOM 2:00 to 3:00 A.M.

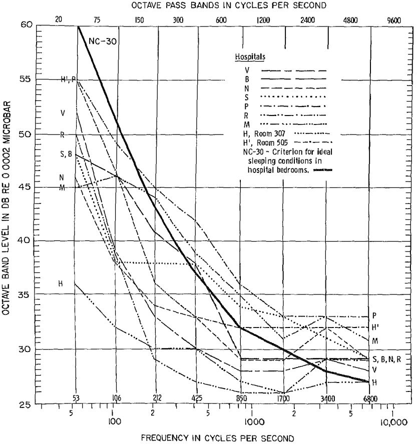
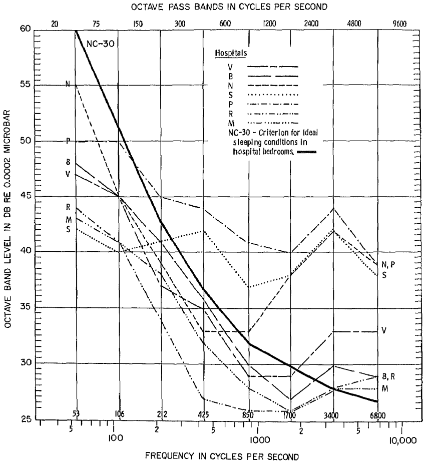


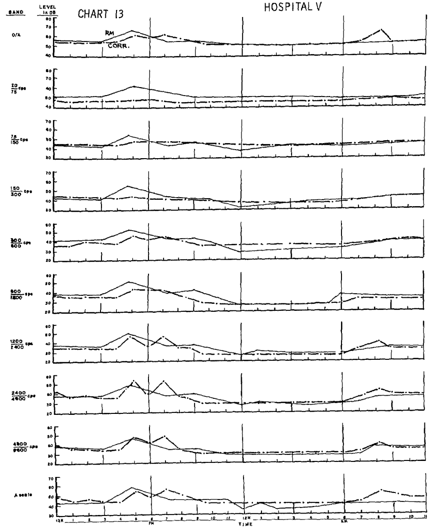
Chart 12 BACKGROUND SOUND LEVELS--CORRIDORS 2:00 to 3:00 A.M.



' back-
sam-
evel,

[illegible] each hospital is shown at the top of each chart and the A-scale value is shown at the bottom; the intervening eight strips show the analyses of background noise by octave bands for patient rooms and corridor readings. Each strip contains two curves: a solid line for the readings in a patient room and a broken line for the corridor readings.

At Hospital H (chart 15), the microphone was moved from the corridor into an empty room, where it remained between 8:30 p.m. and 5:40 a.m. At 12:30 a.m., the room door was closed; note the change in level, as indicated by the broken line.



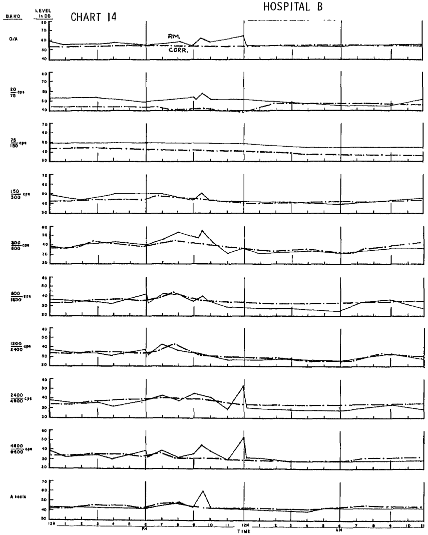


CHART 14
HOSPITAL B
BAND
LEVEL in DB
O/A
RM.
CORR.
$\frac{20}{75}$ cps
$\frac{75}{150}$ cps
$\frac{150}{300}$ cps
$\frac{300}{600}$ cps
$\frac{600}{1200}$ cps
$\frac{1200}{2400}$ cps
$\frac{2400}{4800}$ cps
$\frac{4800}{9600}$ cps
A scale
12N 1 2 3 4 5 6 7 8 9 10 11 12N 1 2 3 4 5 6 7 8 9 10 11
PM
AM
TIME

CHART 15

HOSPITAL H

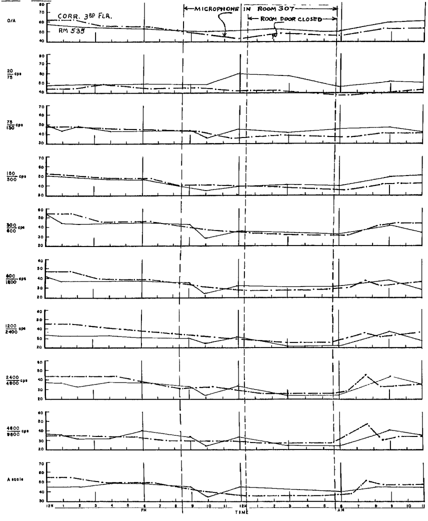


CHART 16

HOSPITAL N

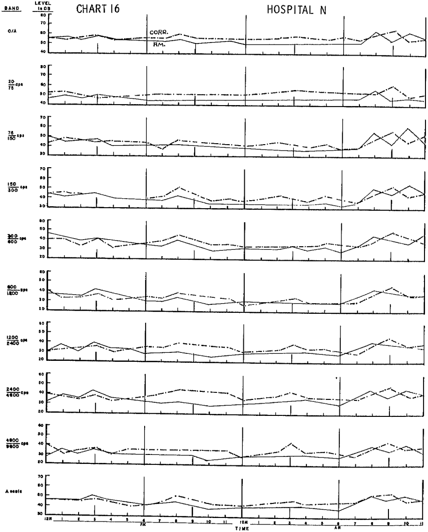


CHART 17

HOSPITAL S

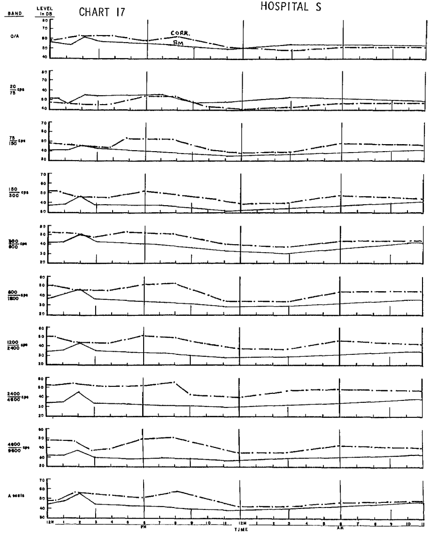
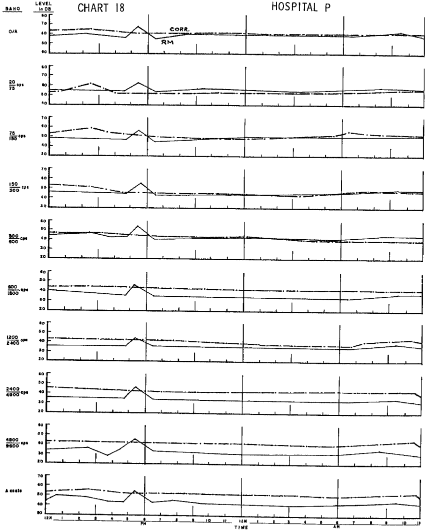


CHART 18

HOSPITAL P



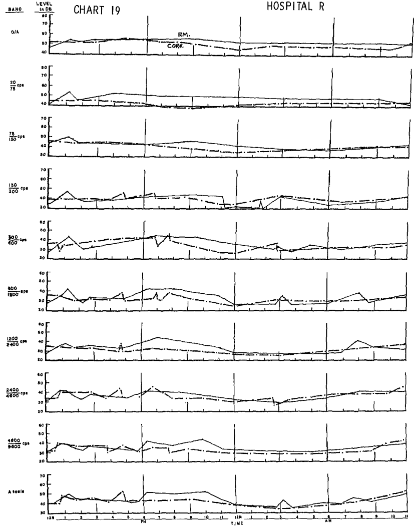
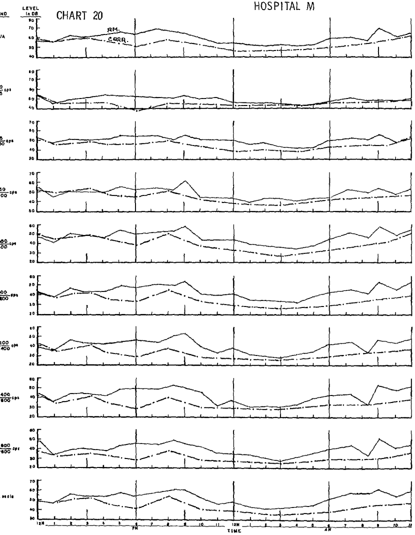


CHART 19 HOSPITAL R

CHART 20

HOSPITAL M

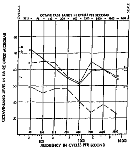


Section 4. *Specific sounds and average background levels.*

These octave band charts show the overall sound levels, indicated on the left side of the grid, and the A-scale values, shown on the right. During the recording, the microphone was located either in a room or in the corridor, as indicated for each group of charts.

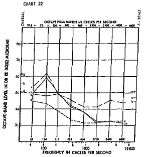
HOSPITAL H (ROOM)

CHART 21



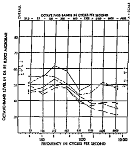
a	3:22 P M	TRUCK START
b	3:27 P M	TRUCK DEPART
c	3:04 P M	AVERAGE BACKGROUND LEVEL

CHART 22



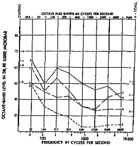
a	2:01 P M	ELEVATOR HUM
b	2:01 P M.	AVERAGE BACKGROUND LEVEL
c	5:58 P M	ELEVATOR DOOR
d	5:58 P M	AVERAGE BACKGROUND LEVEL

CHART 23



a	5:04 P M	DISHWASHER CLOSES
b	5:04 P M	DISHWASHER RUNNING
c	5:04 P M	AVERAGE BACKGROUND LEVEL
d	6:02 P M	PANTRY NOISE
e	6:07 P M	AVERAGE BACKGROUND LEVEL

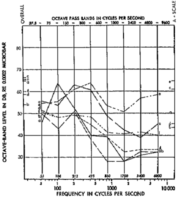
CHART 24



a	8:58 P.M	DOOR SLAM
b	8:58 P M	AVERAGE BACKGROUND LEVEL
c	9:13 P M	TELEPHONE BELL
d	10:01 P.M	AVERAGE BACKGROUND LEVEL

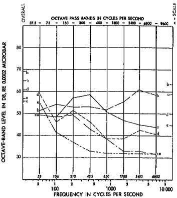
HOSPITAL H (ROOM)

CHART 25



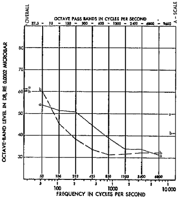
a	10 58 A.M.	ELEVATOR BRAKE
b	10 58 A.M.	AVERAGE BACKGROUND LEVEL
c	7 58 A.M.	PANTRY NOISE
d	7 58 A.M.	AVERAGE BACKGROUND LEVEL
e	9 58 A.M.	PEAK NOISE IN PANTRY
f	9 58 A.M.	AVERAGE BACKGROUND LEVEL

CHART 26



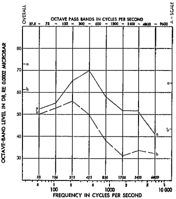
a	2 19 P.M.	WATER, BED PAN
b	2:19 P.M.	BED PAN CLANK
c	2 01 P.M.	AVERAGE BACKGROUND LEVEL
d	2 04 A.M.	TALK IN PANTRY
e	2 04 A.M.	AVERAGE BACKGROUND LEVEL

CHART 27



a	12 25 A.M.	WATER COOLER
b	12 07 A.M.	AVERAGE BACKGROUND LEVEL

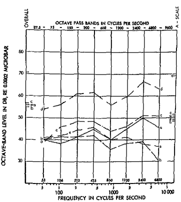
CHART 28



a	7 07 P.M.	CALL SYSTEM
b	7 07 P.M.	AVERAGE BACKGROUND LEVEL

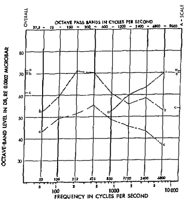
HOSPITAL H (CORRIDOR)

CHART 29



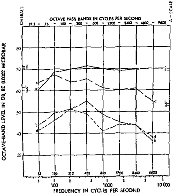
a	8 30 A.M	CART
b	8 30 A.M	AVERAGE BACKGROUND LEVEL
c	8 30 A.M	ELEVATOR
d	9 30 A.M	CART LEAVES ELEVATOR
e	9 30 A M.	AVERAGE BACKGPOUND LEVEL

CHART 30



a	1 42 P M	TELEPHONE
b	1.42 P.M	PAGING SYSTEM
c	1 42 P M.	AVERAGE BACYGROUND LEVEL

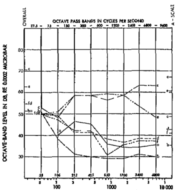
CHART 31



a	1 48 P.M.	DOOR SLAM
b	1 42 P M	AVERAGE BACKGPOUND LEVEL
c	2 30 P.M	DOOR SLAM
d	2 30 P M	AVERAGE BACKGROUND LEVEL

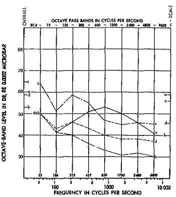
HOSPITAL V (ROOM)

CHART 32



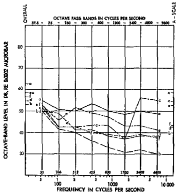
a	5 15 A M.	CHART CASES
b	5.15 A.M.	AVERAGE BACKGROUND LEVEL
c	8 00 A M.	TRAY
d	8 00 A.M.	AVERAGE BACKGROUND LEVEL
e	10 09 A.M.	DROPPED PAN
f	10 09 A.M	AVERAGE BACKGROUND LEVEL

CHART 33



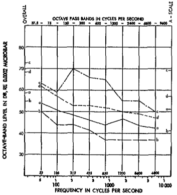
a	7 00 A.M.	LAUGHTER
b	7:00 A.M.	AVERAGE BACKGROUND LEVEL
c	7:18 A.M.	VOICES
d	7:18 A.M.	AVERAGE BACKGROUND LEVEL

CHART 34



a	7 00 A.M.	BANG
b	7 00 A.M.	AVERAGE BACKGROUND LEVEL
c	8 00 A.M.	PHONE
d	8 00 A.M.	AVERAGE BACKGROUND LEVEL
e	11 06 A.M.	CHAIR
f	11-06 A.M.	AVERAGE BACKGROUND LEVEL

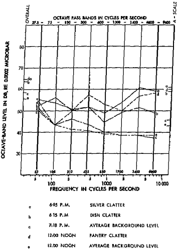
CHART 35



a	9 03 A.M.	CAR APPROACH
b	9:03 A.M.	AVERAGE BACKGROUND LEVEL
c	4.48 P.M.	HORN
d	4:48 P.M.	AVERAGE BACKGROUND LEVEL

HOSPITAL V (ROOM)

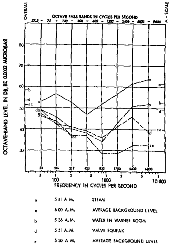
CHART 36



a	6:15 P.M.	SILVER CLATTER
b	6 15 P.M	DISH CLATTER
c	7:18 P.M.	AVERAGE BACKGROUND LEVEL
d	12:00 NOON	PANTRY CLATTER
e	12.00 NOON	AVERAGE BACKGROUND LEVEL

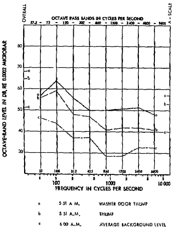
HOSPITAL V (CORRIDOR)

CHART 37



a	5 51 A M.	STEAM
c	6 00 A.M.	AVERAGE BACKGROUND LEVEL
b	5 36 A.M.	WATER IN WASHER ROOM
d	5 51 A.M.	VALVE SQUEAK
e	5 30 A M.	AVERAGE BACKGROUND LEVEL

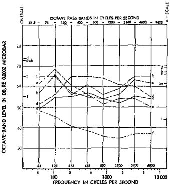
CHART 38



a	5 51 A M.	WASHER DOOR THUMP
b	5 51 A.M.	THUMP
c	6 00 A.M.	AVERAGE BACKGROUND LEVEL

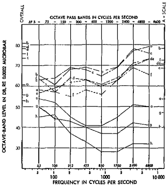
HOSPITAL V (CORRIDOR)

CHART 39



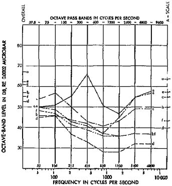
a	6:41 A.M.	PAN
b	6:41 A.M.	WASHER
c	6:41 A.M.	DOOR
d	6:41 A.M.	PAN
e	6:41 A.M.	THUMP
f	7:00 A.M.	AVERAGE BACKGROUND LEVEL

CHART 40



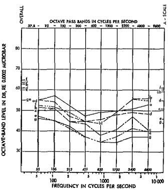
a	11:24 P.M.	UTILITY ROOM CABINET
b	8:21 A.M.	FOOD CART
c	12:18 P.M.	UTILITY CART
d	1:18 P.M.	BED RAILS -- RECOVERY RM
e	3:18 P.M.	UTILITY CART
f	8:15 A.M.	SERVING BREAKFAST
g	9:00 A.M.	AVERAGE BACKGROUND LEVEL
h	11:03 P.M.	AVERAGE BACKGROUND LEVEL

CHART 41



a	8:42 P.M.	NURSES' TALK IN HALL
b	11:24 P.M.	SQUEAKY SHOES
c	4:00 P.M.	ELECTRIC RAZOR
d	8:42 P.M.	AVERAGE BACKGROUND LEVEL
e	11:03 P.M.	AVERAGE BACKGROUND LEVEL
f	4:09 P.M.	AVERAGE BACKGROUND LEVEL

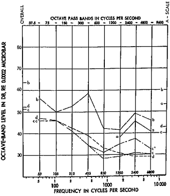
CHART 42



a	6:12 P.M.	DISHWASHER
b	6:24 P.M.	WATER IN PANTRY
c	7:24 A.M.	PANTRY & DISHWASHER
d	1:12 P.M.	PANTRY CLEANUP
e	6:00 P.M.	AVERAGE BACKGROUND LEVEL
f	7:24 A.M.	AVERAGE BACKGROUND LEVEL
g	1:12 P.M.	AVERAGE BACKGROUND LEVEL

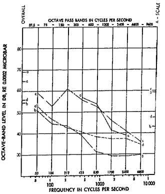
HOSPITAL B (ROOM)

CHART 43



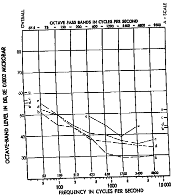
a	9:25 P.M.	BUZZER
b	9 30 P M	AVERAGE BACKGROUND LEVEL PLUS FLOOR POLISHER
c	5 21 A M.	BUZZER, BIRDS
d	5 15 A.M	AVERAGE BACKGROUND LEVEL

CHART 44



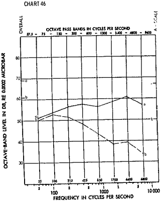
a	10 30 A.M	CALL SYSTEM
b	11 09 A M	AVERAGE BACKGROUND LEVEL
c	9 09 P M	TALK IN NEXT ROOM
d	9 03 P.M	AVERAGE BACKGROUND LEVEL

CHART 45



a	10 30 A M	STEPS
b	11 09 A.M.	AVERAGE BACKGROUND LEVEL
c	1 00 P.M	STEPS
d	1 00 P.M.	AVERAGE BACKGROUND LEVEL

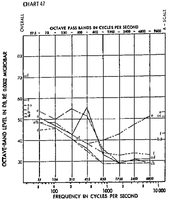
CHART 46



a	8 15 P M	ICE IN PITCHERS (HALL)
b	8 09 P M	AVERAGE BACKGROUND LEVEL

HOSPITAL B (ROOM)

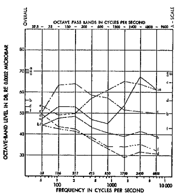
CHART 47



a	3 30 A M	FIRE WHISTLE AND SIREN
b	3 00 A M	AVERAGE BACKGROUND LEVEL
c	4 09 A M	PASSING PLANE
d	4 00 A M	AVERAGE BACKGROUND LEVEL
e	6 06 P M	BIRD
f	6 09 P.M	AVERAGE BACKGROUND LEVEL

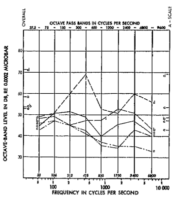
HOSPITAL B (CORRIDOR)

CHART 48



c	5 36 A.M.	BED PAN
d	6-42 A.M	AVERAGE BACKGROUND LEVEL
e	1 36 P M	BED CURTAINS
f	1;36 P.M.	AVERAGE BACKGROUND LEVEL
a	6-54 P.M.	BED ADJUSTMENT
b	6 45 P.M.	AVERAGE BACKGROUND LEVEL

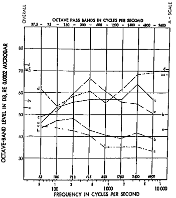
CHART 49



b	9:41 P.M.	WAXER
d	9 51 A.M.	POLISHER
e	9:51 A.M.	AVERAGE BACKGROUND LEVEL
a	9:36 A.M.	WAXES AT NURSES' STATION
c	9 36 A.M.	AVERAGE BACKGROUND LEVEL

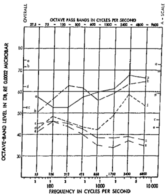
HOSPITAL B (CORRIDOR)

CHART 50



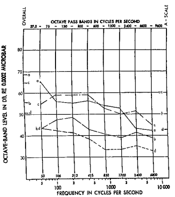
a	6 45 P.M.	CART
b	6 45 P.M	AVERAGE BACKGROUND LEVEL
c	11 33 A.M.	FLOWER CART
e	11 33 A.M.	AVERAGE BACKGROUND LEVEL
d	11 57 A M	FOOD CART

CHART 51



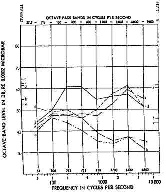
a	2 45 P M	CRASH
c	2 45 P M	AVERAGE BACKGROUND LEVEL
b	4 54 P M	CART CLATTER AND TALK
d	9 54 P M	BUZZER
e	9 36 P M	AVERAGE BACKGROUND LEVEL

CHART 52



a	6 39 P M.	PASSING PLANE
b	6 45 P.M	AVERAGE BACKGROUND LEVEL
c	1:33 P.M	PLANE
d	1 36 P.M	AVERAGE BACKGROUND LEVEL

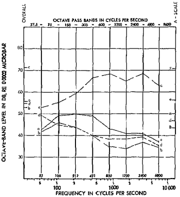
CHART 53



a	7 48 P M	WATER
b	7 48 P M	AVERAGE BACKGROUND LEVEL
c	8 42 P M	BED
e	9 36 P.M	AVERAGE BACKGROUND LEVEL
d	9 36 P M	NURSES STATION DOOR

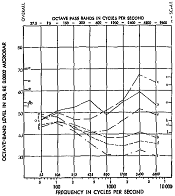
HOSPITAL B (CORRIDOR)

CHART 54



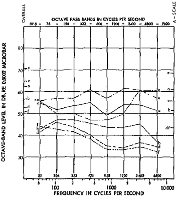
a	8 42 P M	HARD HEELS
b	9 36 P M	AVERAGE BACKGROUND LEVEL
c	7 36 A.M.	FOOD SERVICE TALK
d	7 36 A.M	AVERAGE BACKGROUND LEVEL

CHART 55



a	4 48 P.M	DISHES
b	4 48 P.M	AVERAGE BACKGROUND LEVEL
c	5 45 P M	BANGING PAN
d	5 42 P M	AVERAGE BACKGROUND LEVEL
e	1 54 A.M	PANTRY NOISE
f	1 54 A.M.	AVERAGE BACKGROUND LEVEL

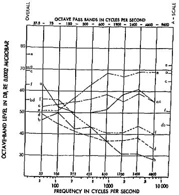
CHART 56



a	7 45 P.M.	DOOR
b	7 45 P.M.	AVERAGE BACKGROUND LEVEL
c	8 42 P M.	DOOR SLAM
d	9 36 P.M	AVERAGE BACKGROUND LEVEL
e	1 33 P.M.	DOOR SLAM
f	1:36 P.M.	AVERAGE BACKGROUND LEVEL

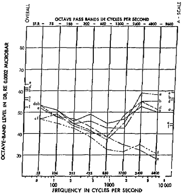
HOSPITAL N (ROOM)

CHART 57



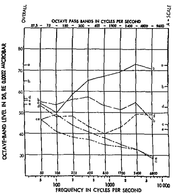
a	11 45 A.M	DISH
b	11 45 A M	AVERAGE BACKGROUND LEVEL
c	12 51 P.M	UTILITY PAN
d	12 51 P.M	AVERAGE BACKGROUND LEVEL
e	7 51 A M	DROPPED PAN
f	7 45 A M.	AVERAGE BACKGROUND LEVEL

CHART 58



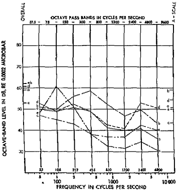
a	12 39 P M	WATER
b	12 39 P.M	STEAM
c	12 21 P.M	AVERAGE BACKGROUND LEVEL
d	1 45 P.M.	UTILITY ROOM WATER
e	1 45 P.M	UTILITY ROOM STEAM
f	1 48 P M	AVERAGE BACKGROUND LEVEL

CHART 59



a	12 21 P.M	PICK UP, FOOD CART
b	12 21 P M	CART ROLLS ON ELEVATOR
c	12 21 P M	AVERAGE BACKGROUND LEVEL
d	5 12 P M	RETURNING TRAYS TO CART
e	4 45 P.M	AVERAGE BACKGROUND LEVEL

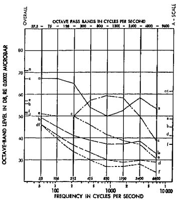
CHART 60



a	2 03 P M.	FLOOR POLISHER
b	2 06 P.M	FLOOR POLISHER
c	1 48 P.M.	AVERAGE BACKGROUND LEVEL
d	9 57 A.M.	SCRUB MACHINE
e	9 45 A M.	AVERAGE BACKGROUND LEVEL

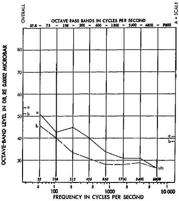
HOSPITAL N (ROOM)

CHART 61



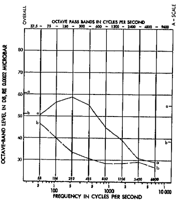
a	12 51 P.M.	TRUCK
b	12 51 P.M.	AVERAGE BACKGROUND LEVEL
c	7 09 P.M.	HORN
d	6 45 P.M.	AVERAGE BACKGROUND LEVEL
e	10 00 P.M	CAR PASSING
f	9 45 P M.	AVERAGE BACKGROUND LEVEL

CHART 62



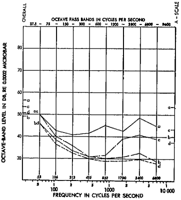
a	10 45 P.M	ELEVATOR
b	10 45 P.M	AVERAGE BACKGROUND LEVEL

CHART 63



a	11:00 P.M.	CAR IN PARKING LOT
b	10 45 P.M.	AVERAGE BACKGROUND LEVEL

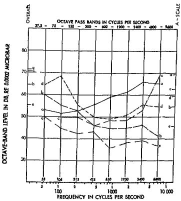
CHART 64



a	1:48 A.M	NOISE AT N.S.
b	1 45 A.M.	AVERAGE BACKGROUND LEVEL
c	1:06 A.M.	CALL BUZZER
d	12:51 A.M.	AVERAGE BACKGROUND LEVEL

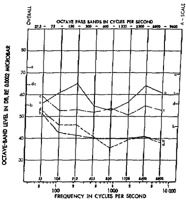
HOSPITAL N (CORRIDOR)

CHART 65



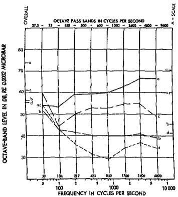
a	8 57 A.M.	VACUUM CLEANER
b	8 48 A.M.	AVERAGE BACKGROUND LEVEL
c	9 45 A.M.	SQUEAK
d	9 45 A.M.	SLAM
e	9 45 A.M	AVERAGE BACKGROUND LEVEL

CHART 66



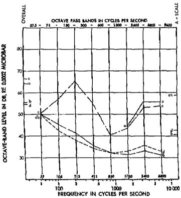
a	11.48 A.M.	DOOR
b	11 48 A.M	AVERAGE BACKGROUND LEVEL
c	8 45 A.M	DOOR CLOSER
d	8 45 A.M.	AVERAGE BACKGROUND LEVEL

CHART 67



a	11 48 A M	MEDICINE CART
b	11:48 A.M.	AVERAGE BACKGROUND LEVEL
c	3 57 A.M.	MEDICINE CART
d	3 45 A.M	AVERAGE BACKGROUND LEVEL

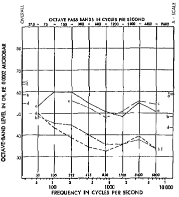
CHART 68



a	1 45 P M	STEAM, UTILITY ROOM
b	1 45 P.M	AVERAGE BACKGROUND LEVEL
c	6 06 P.M.	STEAM, WASHER
d	5 45 P.M.	AVERAGE BACKGROUND LEVEL

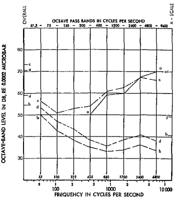
HOSPITAL N (CORRIDOR)

CHART 69



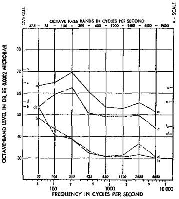
a	2 45 P.M	NURSES' STATION, TALK
b	2 45 P M	AVERAGE BACKGROUND LEVEL
c	11 06 P M	NURSES' STATION, COUGH
d	10 45 P M.	AVERAGE BACKGROUND LEVEL

CHART 70



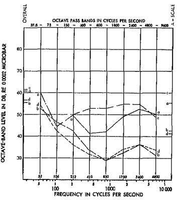
a	6 00 P.M.	BED CURTAINS
b	5 45 P M.	AVERAGE BACKGROUND LEVEL
c	7:48 A M	TRAY, TO FOOD CART
d	7 48 A.M	AVERAGE BACKGROUND LEVEL

CHART 71



a	4 06 P M	TRUCK
b	3 48 P.M	AVERAGE BACKGROUND LEVEL
c	5.48 A.M.	CAP OR TRUCK
d	5 45 A.M.	AVERAGE BACKGROUND LEVEL

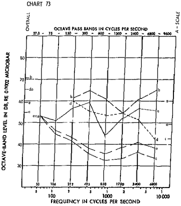
CHART 72



a	1:48 A M	NURSES' STATION, CHART CASE
b	1 48 A M.	AVERAGE BACKGROUND LEVEL
c	3 57 A M.	NURSES' STATION, MEDICAL CART
d	3 45 A.M	AVERAGE BACKGROUND LEVEL

HOSPITAL N (CORRIDOR)

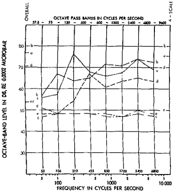
CHART 73



a	4 45 A M	WATER
b	4 45 A.M	FAUCET SQUEAK
c	4 45 A M	AVERAGE BACKGROUND LEVEL
d	7 48 A M	CHAIR, SCRAPE
e	7 48 A M	AVERAGE BACKGROUND LEVEL

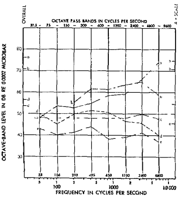
HOSPITAL S (CORRIDOR)

CHART 74



a	6 09 A.M	PANS
b	6 09 A.M	ICE
c	6 09 A M	AVERAGE BACKGROUND LEVEL
d	10 03 A M	KITCHEN
e	10 03 A M	AVERAGE BACKGROUND LEVEL

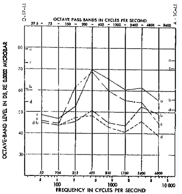
CHART 75



a	8 51 A M.	GLASSWARE
b	8 51 A M	AVERAGE BACKGROUND LEVEL
c	9 09 A M	WASHING SILVER
d	11 09 P M	FLUSHING
e	11 09 P M	AVERAGE BACKGROUND LEVEL

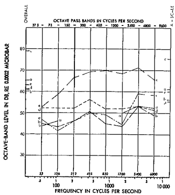
HOSPITAL S (CORRIDOR)

CHART 76



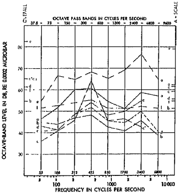
a	2 00 P.M	CALL SYSTEM
b	1 48 P M	AVERAGE BACKGROUND LEVEL
c	2 45 P M	CALL SYSTEM
d	2 45 P.M.	AVERAGE BACKGROUND LEVEL

CHART 77



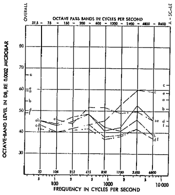
a	2 12 P M.	HAND BELL
b	1 48 P M.	AVERAGE BACKGROUND LEVEL
c	5 09 P.M	FOOD SERVICE TALK
d	4 45 P.M	AVERAGE BACKGROUND LEVEL
e	1 51 P.M	TELEPHONE BELL
f	1 48 P.M	AVERAGE BACKGROUND LEVEL

CHART 78



a	2:12 P.M.	ELEVATOR DOOR
b	2:45 P.M	AVERAGE BACKGROUND LEVEL
c	3 48 P.M.	TWO ELEVATOR POUNDS (C & C')
d	3 45 P.M.	AVERAGE BACKGROUND LEVEL
e	6:09 P.M.	ELEVATOR DOOR
f	5 48 P.M.	AVERAGE BACKGROUND LEVEL

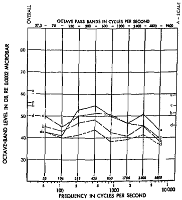
CHART 79



a	2 51 P.M.	DISHWASHER
b	2 45 P.M	AVERAGE BACKGROUND LEVEL
c	11 09 P.M	TELEPHONE
d	11 09 P.M.	AVERAGE BACKGROUND LEVEL
e	3 09 A.M.	DOOR SLAM
f	3 09 A.M.	AVERAGE BACKGROUND LEVEL

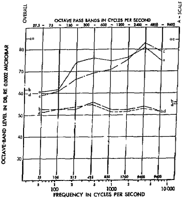
HOSPITAL S (CORRIDOR)

CHART 80



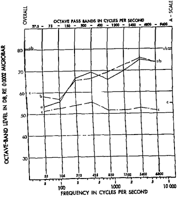
a	3 03 P.M	WATER INTO PAN
b	2 45 P.M.	AVERAGE BACKGROUND LEVEL
c	11 09 P.M	FLUSH
d	11 09 P M	AVERAGE BACKGROUND LEVEL

CHART 81



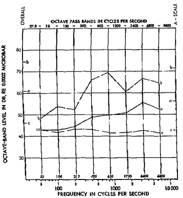
a	4 45 P M	ICE MACHINE
b	4 45 P.M	AVERAGE BACKGROUND LEVEL
c	6 12 P.M	ICE MACHINE
d	5 48 P.M	AVERAGE BACKGROUND LEVEL

CHART 82



a	5 48 P.M.	DISHES IN CART
b	5 51 P.M	DISHES IN CART
c	5 48 P M	AVERAGE BACKGROUND LEVEL

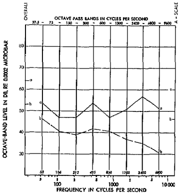
CHART 83



a	9 57 P.M.	SHARP CLATTER
b	9 57 P.M	AVERAGE BACKGROUND LEVEL
c	9 12 P.M	CHAIR SCRAPE

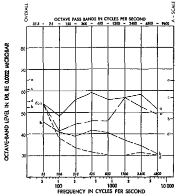
HOSPITAL S (ROOM)

CHART 84



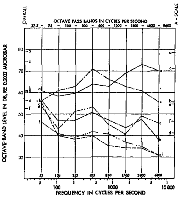
a	1 09 P.M	ELEVATOR
b	1.09 P M	AVERAGE BACKGROUND LEVEL

CHART 85



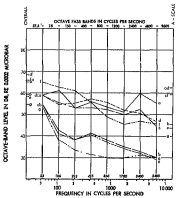
a	1:09 P M	CART
b	1:09 P.M.	AVERAGE BACKGROUND LEVEL
c	5:09 A M.	CART
d	2 54 A M	AVERAGE BACKGROUND LEVEL

CHART 86



a	2 03 P M.	DISH CLATTER
b	2 03 P.M	AVERAGE BACKGROUND LEVEL
c	7:21 P.M.	MOVING EQUIPMENT
d	7:21 P.M.	AVERAGE BACKGROUND LEVEL
e	1 09 P.M.	WATER IN SINK
f	1:09 P.M.	AVERAGE BACKGROUND LEVEL

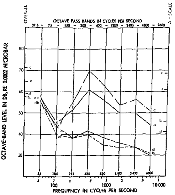
CHART 87



a	3 45 P.M.	TRUCK
b	3 06 P.M.	AVERAGE BACKGROUND LEVEL
c	5 06 P.M.	CAR START
e	5 06 P.M.	AVERAGE BACKGROUND LEVEL
d	5 06 P.M.	CAR DOOR SLAM
f	6:12 A.M.	TRUCK START
g	2:54 A.M.	AVERAGE BACKGROUND LEVEL

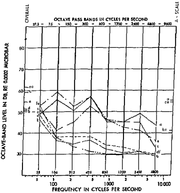
HOSPITAL S (ROOM)

CHART 88



a	3 06 P.M.	CALL SYSTEM
b	3 06 P.M.	AVERAGE BACKGROUND LEVEL
c	7 21 P.M.	LOUD CALL
d	7 21 P.M.	AVERAGE BACKGROUND LEVEL

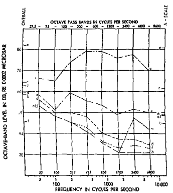
CHART 89



a	9 12 P.M.	BOAT WHISTLE
b	9 12 P.M.	AVERAGE BACKGROUND LEVEL
c	9 57 P.M.	TRAIN
d	9 57 P.M.	AVERAGE BACKGROUND LEVEL
e	5 09 A.M.	BOAT WHISTLE
f	2 54 A.M.	AVERAGE BACKGROUND LEVEL

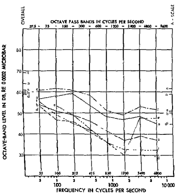
HOSPITAL P (ROOM)

CHART 90



a	5 30 A.M.	BIRD
b	5 30 A.M.	AVERAGE BACKGROUND LEVEL
c	9 39 A.M.	BIRD
d	9 30 A.M.	AVERAGE BACKGROUND LEVEL
e	8 58 P.M.	HORN
f	8 30 P.M.	AVERAGE BACKGROUND LEVEL

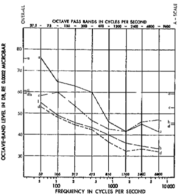
CHART 91



a	2 15 P.M.	WATER TAP
b	2 15 P.M.	AVERAGE BACKGROUND LEVEL
c	2 36 P.M.	ROOM AIR CONDITIONER
d	3 51 P.M.	AVERAGE BACKGROUND LEVEL
e	2 30 A.M.	GLASS CLINK
f	2 30 A.M.	AVERAGE BACKGROUND LEVEL

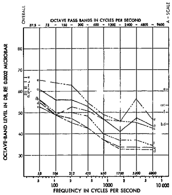
HOSPITAL P (ROOM)

CHART 92



a	12 15 P.M	CAR SHIFT
b	12:15 P.M	AVERAGE BACKGROUND LEVEL
c	8 30 P.M.	PASSING CAR
d	8 30 P M	AVERAGE BACKGROUND LEVEL

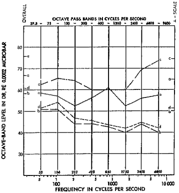
CHART 93



a	10 36 P M	NOISE AT NURSES' STATION
b	10 36 P M	AVERAGE BACKGROUND LEVEL
c	11 30 P.M	CHART CASE
d	11 30 P.M.	AVERAGE BACKGROUND LEVEL
e	9 39 A M	CART WHEEL SQUEAK
f	9 30 A M	AVERAGE BACKGROUND LEVEL

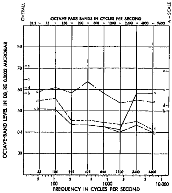
HOSPITAL P (CORRIDOR)

CHART 94



a	3 33 A.M	OXYGEN TANK
b	3 33 A.M.	AVERAGE BACKGROUND LEVEL
c	8 57 A.M.	CLEANING BUCKET
	8 30 A.M.	AVERAGE BACKGROUND LEVEL

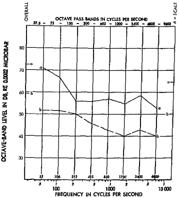
CHART 95



a	3 57 A.M	HAND BELL
b	3 33 A M.	AVERAGE BACKGROUND LEVEL
c	4 33 P.M.	CHART
d	4 30 P M.	AVERAGE BACKGROUND LEVEL

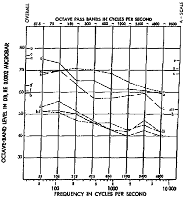
HOSPITAL P (CORRIDOR)

CHART 96



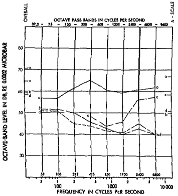
a	11 54 A.M	TRUCK OR CAR START
b	11 36 A.M.	AVERAGE BACKGROUND LEVEL

CHART 97



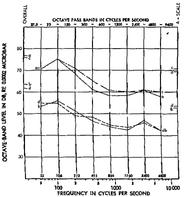
a	11 36 A.M	DOOR SLAM
b	11 36 A.M.	AVERAGE BACKGROUND LEVEL
c	12 39 P.M.	DOOR SLAM
d	12 33 P.M.	AVERAGE BACKGROUND LEVEL
e	6 36 P.M.	DOOR SLAM
f	6 30 P.M.	AVERAGE BACKGROUND LEVEL

CHART 98



a	11 39 A M	WATER
b	11 36 A.M	AVERAGE BACKGROUND LEVEL
c	5 30 A.M	WATER
d	5 30 A.M.	AVERAGE BACKGROUND LEVEL

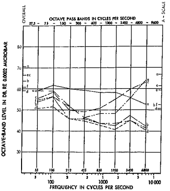
CHART 99



a	12 36 P.M	CABINET DOOR SLAM
b	12 33 P M.	AVERAGE BACKGROUND LEVEL
c	3 36 P.M.	CABINET DOOR SLIDING
d	3 36 P M	AVERAGE BACKGROUND LEVEL

HOSPITAL P (CORRIDOR)

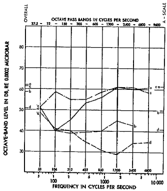
CHART 100



a	12 39 P M	TELEPHONE BELL
b	12 33 P.M	AVERAGE BACKGROUND LEVEL
c	10 45 P.M.	TELEPHONE BELL
d	10 33 P M	AVERAGE BACKGROUND LEVEL
e	4 33 P M	TELEPHONE BELL
f	4 30 P M	AVERAGE BACKGROUND LEVEL

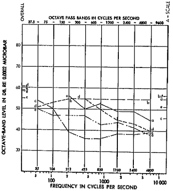
HOSPITAL R (ROOM)

CHART 101



a	8 00 A M	CART MOVING
b	8 00 A M	AVERAGE BACKGROUND LEVEL
c	9 54 A M.	CART
d	9 48 A.M	AVERAGE BACKGROUND LEVEL

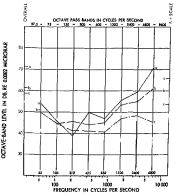
CHART 102



a	3 00 P.M	TALK AT NURSES' STATION
b	4 06 P.M	TALK
c	3 45 P M	AVERAGE BACKGROUND LEVEL
d	7 12 P.M	VOICES
e	7 12 P.M	AVERAGE BACKGROUND LEVEL

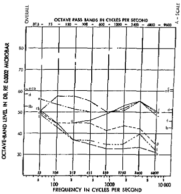
HOSPITAL R (ROOM)

CHART 103



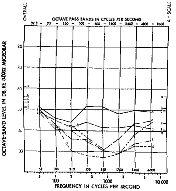
a	3 06 P M.	PHONE BELL AT NURSES' STATION
b	7 00 P.M.	PHONE BELL
c	7 00 P M	AVERAGE BACKGROUND LEVEL

CHART 104



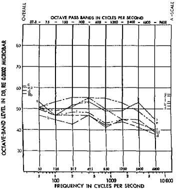
a	5 45 P M	DISHES
b	5 45 P.M	AVERAGE BACKGROUND LEVEL
c	6 51 P M	CART
d	6 51 P M	AVERAGE BACKGROUND LEVEL
e	9 09 A M	PAN
f	9 09 A M	AVERAGE BACKGROUND LEVEL

CHART 105



a	6 17 P M	CHOPPING ICE
b	6 17 P M	AVERAGE BACKGROUND LEVEL
c	11 15 P M	NOISES
d	11 15 P M	AVERAGE BACKGROUND LEVEL
e	9 48 A M	BOTTLES
f	9 48 A M	AVERAGE BACKGROUND LEVEL

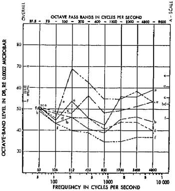
CHART 106



a	6 45 P M	TALK
b	6 45 P M	AVERAGE BACKGROUND LEVEL
c	7 12 P M	VOICES
d	7 12 P M	AVERAGE BACKGROUND LEVEL
e	9 57 P M	TALK
f	9 57 P.M	AVERAGE BACKGROUND LEVEL

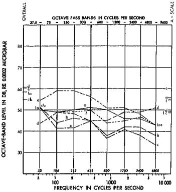
HOSPITAL R (ROOM)

CHART 107



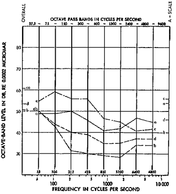
a	6 54 P M.	PHONE
b	6 54 P.M	AVERAGE BACKGROUND LEVEL
c	8 57 P.M	BUZZER
d	8 57 P.M	AVERAGE BACKGROUND LEVEL
e	10 57 P.M	SQUEAK
f	11 03 P.M.	AVERAGE BACKGROUND LEVEL

CHART 108



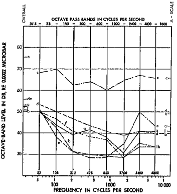
a	8 09 P.M.	FAN
b	10 45 P.M.	FAN
c	10.45 P M.	AVERAGE BACKGROUND LEVEL
d	8 18 P.M.	CLANK
e	9 45 P.M.	THUMPS
f	9 45 P.M	AVERAGE BACKGROUND LEVEL

CHART 109



a	11 54 P.M.	DOOR
b	12 03 A.M	AVERAGE BACKGROUND LEVEL
c	10 57 P.M	DOOR
d	11 03 P.M	AVERAGE BACKGROUND LEVEL

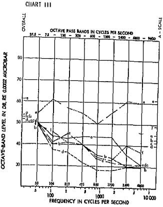
CHART 110



a	12 03 A M.	HORN
b	12 03 A M.	AVERAGE BACKGROUND LEVEL
c	1 15 P M.	TRUCK START
d	1 15 P.M.	AVERAGE BACKGROUND LEVEL
e	5 45 A.M.	BIRD
f	5 45 A M.	AVERAGE BACKGROUND LEVEL

HOSPITAL R (ROOM)

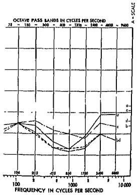
CHART 111



a	4 47 A.M.	TRAIN HORN
b	4:47 A.M.	AVERAGE BACKGROUND LEVEL
c	1:51 A.M.	TRAIN
d	1:51 A.M.	AVERAGE BACKGROUND LEVEL
e	7:57 A.M.	CAR START
f	7:57 A.M	AVERAGE BACKGROUND LEVEL

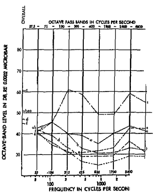
HOSPITAL R (CORRIDOR)

2



3:45 P.M.	TYPING
3:45 P.M.	AVERAGE BACKGROUND LEVEL
6:45 P.M.	DIALING
6:45 P.M.	AVERAGE BACKGROUND LEVEL

CHART 113

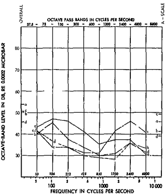


a	3 51 P.M.	CLICK
b	3 51 P.M	AVERAGE BACKGROUND –
c	10.52 P.M.	CHAIR
d	10.51 P.M.	AVERAGE BACKGROUND LEVEL
e	12:45 A.M.	SWITCH
f	12-00 A.M.	AVERAGE BACKGROUND LEVEL

SCALE

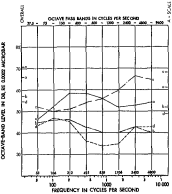
HOSPITAL R (CORRIDOR)

CHART 114



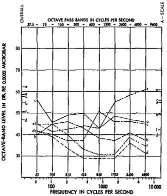
a	7 03 P M	DOOR
b	7 03 P.M.	AVERAGE BACKGROUND LEVEL
c	11 57 P M.	DOOR
d	11 57 P.M	AVERAGE BACKGROUND LEVEL

CHART 115



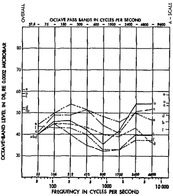
a	4.45 P.M.	CART
b	4 45 P.M	AVERAGE BACKGROUND LEVEL
c	10 51 A M	CART
d	10 45 P.M	AVERAGE BACKGROUND LEVEL

CHART 116



a	6:51 P.M.	PHONE
b	6 51 P M.	AVERAGE BACKGROUND LEVEL
c	10.45 P.M.	BUZZER
d	10·51 P.M.	AVERAGE BACKGROUND LEVEL
e	7:03 A.M	PHONE
f	8 45 A.M.	AVERAGE BACKGROUND LEVEL

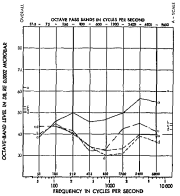
CHART 117



a	6:57 P.M.	WATER
b	6 57 P.M.	AVERAGE BACKGROUND LEVEL
c	7:45 P.M.	WATER
d	7·45 P.M.	AVERAGE BACKGROUND LEVEL
e	2:48 A.M.	FLUSH
f	2·48 A.M.	AVERAGE BACKGROUND LEVEL

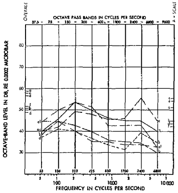
HOSPITAL R (CORRIDOR)

CHART 118



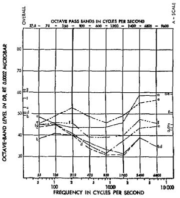
a	6 57 P M	PAN CLANK
b	6 57 P M.	AVERAGE BACKGROUND LEVEL
c	11 45 A M	PAN NOISE
d	11 45 A M.	AVERAGE BACKGROUND LEVEL

CHART 119



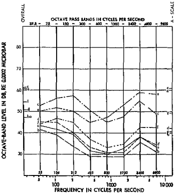
a	7 54 P.M	MALE VOICE
b	7 54 P M	AVERAGE BACKGROUND LEVEL
c	9 06 P.M.	VOICE
d	9 06 P M.	AVERAGE BACKGROUND LEVEL
e	12 45 P M	NURSE TALK
f	12 45 P M	AVERAGE BACKGROUND LEVEL

CHART 120



a	9 51 P M.	DISHES
b	9 06 P.M	AVERAGE BACKGROUND LEVEL
c	8 45 A.M.	DISH
d	8 45 A.M	AVERAGE BACKGROUND LEVEL
e	10 48 A M.	CHOPPING ICE
f	10 48 A.M.	AVERAGE BACKGROUND LEVEL

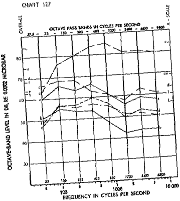
CHART 121



a	10 51 P.M	SOFT DRINK MACHINE
b	10 51 P.M	AVERAGE BACKGROUND LEVEL
c	7 45 A.M.	ELEVATOR DOOR
d	8 45 A.M	AVERAGE BACKGROUND LEVEL
e	10 45 A.M.	DOOR
f	10 45 A.M	AVERAGE BACKGROUND LEVEL

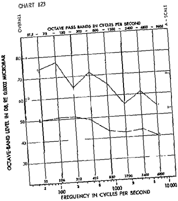
HOSPITAL M (ROOM)

CHART 122



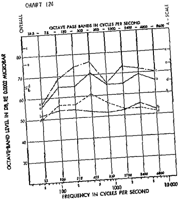
a	7 41 A.M	BUZZER
b	7 41 A.M.	AVERAGE BACKGROUND LEVEL
c	9 03 A M	PAN
d	9·03 A M	AVERAGE BACKGROUND LEVEL
e	10 09 A M	SLAM
f	10 09 A M.	AVERAGE BACKGROUND LEVEL

CHART 123



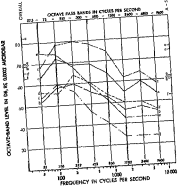
a	2 16 P.M.	TRUCK START
b	2 52 P M	AVERAGE BACKGROUND LEVEL

CHART 124



a	5 12 P.M	FOOD CART
b	5 12 P.M.	AVERAGE BACKGROUND LEVEL
c	9.21 A.M	CART AND HAMMERING

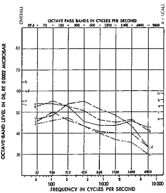
CHART 125



a	5 39 P.M	PLANE
b	5 39 P.M	AVERAGE BACKGROUND LEVEL
c	9 03 P.M.	TRAIN
d	9 03 P.M	AVERAGE BACKGROUND LEVEL
e	2:37 A.M.	PLANE
f	2:37 A.M.	AVERAGE BACKGROUND LEVEL

HOSPITAL M (ROOM)

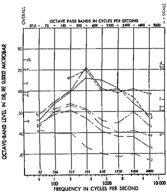
CHART 126



a	11 58 P M	CAP
b	11 58 P M	DOOR
c	11 58 P M	AVERAGE BACKGROUND LEVEL
d	3 12 A M	TRAIN
e	3 12 A M.	AVERAGE BACKGROUND LEVEL

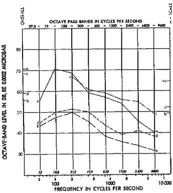
HOSPITAL M (CORRIDOR)

CHART 127



a	1 05 P M	CALL SYSTEM
b	2 05 P M	CALL SYSTEM
c	2 05 P M	AVERAGE BACKGROUND LEVEL
d	7 02 P M	CALL SYSTEM
e	7 02 P.M.	AVERAGE BACKGROUND LEVEL
f	12 28 A M	CALL SYSTEM
g	12 08 A M	AVERAGE BACKGROUND LEVEL

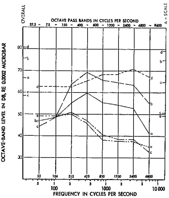
CHART 128



a	1 05 P M	MOVING FURNITURE
b	1 05 P M	AVERAGE BACKGROUND LEVEL
c	8 14 P M	MOVING FURNITURE
d	7 59 P.M.	AVERAGE BACKGROUND LEVEL

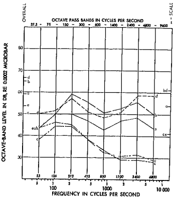
HOSPITAL M (CORRIDOR)

CHART 129



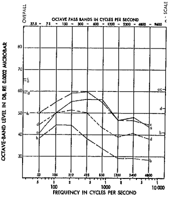
a	2 14 P.M	FLOOR POLISHER
b	2 05 P M.	AVERAGE BACKGROUND LEVEL
c	2 20 P M	FLOOR POLISHER
d	9 38 A M	CLEANING
e	9 38 A M.	AVERAGE BACKGROUND LEVEL

CHART 130



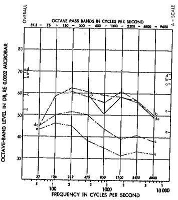
a	6 02 P M	BATH RUNNING
b	6 02 P.M	BATH FAUCET
c	6 05 P M	AVERAGE BACKGROUND LEVEL
d	10 20 P M	RATTLE, PANS OR PAILS
e	10 20 P.M.	AVERAGE BACKGROUND LEVEL

CHART 131



a	6 08 P M.	FOOT STEPS
b	6 05 P M	AVERAGE BACKGROUND LEVEL
c	8 08 P.M.	VISITORS' HEELS
d	7 59 P.M.	AVERAGE BACKGROUND LEVEL

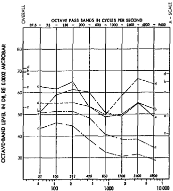
CHART 132



a	7 02 P.M.	BUZZER
b	8 14 P.M.	BUZZER
c	7:59 P M.	AVERAGE BACKGROUND LEVEL
d	9 05 P.M.	CLATTER AND CALL SYSTEM
e	9:05 P.M	AVERAGE BACKGROUND LEVEL

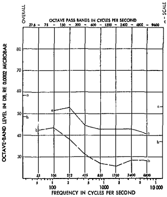
HOSPITAL M (CORRIDOR)

CHART 133



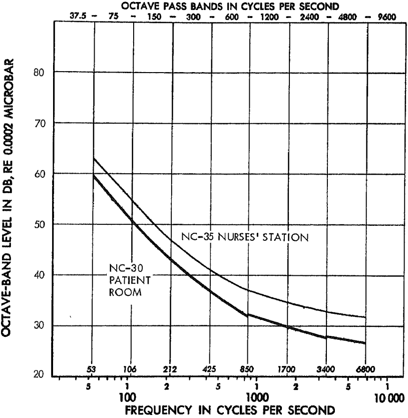
a	10 08 P.M	DOOR
b	10 20 P M	SQUEAKY DOOR SLAM
c	10 20 P M	AVERAGE BACKGROUND LEVEL
d	10 50 A M	BED CURTAIN
e	10 38 A M.	AVERAGE BACKGROUND LEVEL

CHART 134



a	2 05 A M	ELEVATOR DOOR
b	2 05 A M	AVERAGE BACKGROUND LEVEL

CHART 135. NOISE CRITERIA (NC)



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